Copy No. 36

PRODUCTION ENGINEERING MEASURE

MECHANIZATION FOR 2N559 & 2N1094 TRANSISTORS

PHASE 1

FINAL ENGINEERING REPORT

FOR THE PERIOD

APRIL 30, 1959 TO DECEMBER 31, 1962

OBJECT:

1. Design and Fabricate High-Volume Production Equipment
2. Establish Mechanized Production Line

CONTRACT NO. DA-36-039-SC-72729

ORDER NO. 53888-PP-56-81-81

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ABSTRACT

During development of the Nike Zeus anti-missile missile, it became apparent that large quantities of 2N559 and 2N1094 transistors would be needed as part of this system. Quantities forecast were so large that extraordinary manufacturing capabilities would be required. Since the semiconductor industry was less than ten years old and tooled for low volume production, the scope of Contract No. DA-36-039-SC-72729 was expanded to provide mechanized equipment for high volume production of 2N559 and 2N1094 transistors.

During Phase 1 of the 2N559-2N1094 Mechanization Program, 22 machines for 20 manufacturing operations were built. This report reviews the work done during Phase 1, April 30, 1959 to December 31, 1962, while developing and testing the machines. Each mechanized operation is described; problems encountered during development and operation of the machine are reviewed; mechanized operations are evaluated, and recommendations for further developments and refinements are presented.

A 2N559 pilot production run and four mechanized production runs - for 2N560, 2N1051, 2N1094, and 2N1195 transistors - demonstrated the production capability of the mechanized line. Distribution of Group A electrical parameters and summaries of Group B tests presented in this report indicate the quality of the five transistor types as Phase 1 ended.

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PURPOSE

Early forecasts of the Nike Zeus missile defense network indicated that large quantities of 2N559 and 2N1094 transistors would be required. Since many transistor manufacturing operations were slow, manual operations, it was evident that the production capability would have to be increased by mechanizing various operations. Overall production planning is currently based on the objective production levels shown in the latest Nike Zeus Defense Production Program.

In 1956, this Production Engineering Measure was initiated to develop two diffused semiconductor devices, Device 7 (2N694) and Device 12 (2N537). Then a mechanization program for Device 12 was added to provide a background in anticipation of mechanization for Nike Zeus. After Nike Zeus developments advanced sufficiently, mechanization for Device 12 was limited to four operations: Wafer Bonding, Contact Wire Bonding, Vacuum Bake-Out and Seal, and D-C and High Frequency Testing. (The Final Report submitted March 1962 reviews all Device 7 and Device 12 developments.) Other operations being mechanized for Device 12 were redirected for the 2N559-2N1094 Mechanization Program.

Since initiating the 2N559-2N1094 Mechanization Program, production planning for Nike Zeus has undergone several changes. Recent changes have decreased the number of machines required as well as extended the program. Specific goals set for various phases of the Mechanization Program follow:

PHASE 1

1. Provide production engineering to establish manufacturing techniques and operations for mechanized production

of 2N559 and 2N1094 transistors.

2. Design, develop, and provide the necessary machinery tooling and test equipment to establish a limited production line capable of producing at least 24,000 transistors per 2-shift, 8-hour, 5-day week. The number and type of machine per Contract Modification No. 23 shall be as follows:

Contract Item No.	Operation and Type of Machine	Quantity
6.2.1*	Cleaning Header Lead Wire	1
6.2.2*	Piece Part Cleaning	1
6.2.3*	Piece Part Gold Plating	1
6.2.4	Platform Lead Welding	1
6.2.5	Header Assembling	1
6.2.6*	Header Glassing	1
6.2.7	Header Lead Trimming	1
6.2.8*	Strip Perforating and Welding	2
6.2.9*	Header Continuous Rack Plating	1
6.2.10	Can Getter Assembling	1
6.2.11*	Slice Scribing	1
6.2.12	Wafer Breaking, Screening and Loading	1
6.2.13	Wafer Bonding	1
6.2.14*	Wire Bonding	2
6.2.15	Final Cleaning	1
6.2.16	Closure Welding	1
6.2.17	Card Loading	1
6.2.18	Testing and Date Stamping-2N559	1

Contract Item No.	Operation and Type of Machine	Quantity
6.2.19*	Data Handling	1
6.2.20	Card Packaging	1

*Machines also capable of processing components of 2N560, 2N1051 and 2N1195 transistors.

PHASE 2

3. Modification of production equipment of Item 2, above, and transistor processing in accordance with advanced semiconductor technology in order to increase the device assembly yield.

4. Design, fabricate, and refine the indicated quantities of machines for each of the following operations:

Contract Item No.	Operation and Type of Machine	Quantity
6.3.4.1	Wire Bonding	1
6.3.4.2	Handling Tray Loading	1
6.3.4.3	Tinning Transistor Leads	1

5. Design, fabricate, and refine necessary additional tooling to increase the capability of tooling already provided in order to increase the production level of the mechanized production line to at least 60,000 transistors conforming to applicable specifications per 2-shift, 8-hour, 5-day week.

PHASE 3

6. Modification of transistor processing and production equipment provided during Phase 1 and 2 in accordance with advanced semiconductor technology in order to

accomplish an additional increase in the device assembly production yield.

7. Prepare Mobilization Planning Report.

NARRATIVES AND DATA

SECTION I

INTRODUCTION

I Background

At inception of the 2N559-2N1094 Mechanization Program, transistor assembly and testing required extensive manual effort. Tooling and test equipment were simple. Quality as well as output were, in many instances, dependent on operator judgment and skill. The batch-type operations used for header plating and header lead cleaning could provide high-volume output but processed parts did not have the uniformity required by the mechanized equipment. Only germanium processing, slice diffusion and evaporation, and certain piece part cleaning operations could, with minor process refinements, meet anticipated production requirements.

II Authorization

Since the state-of-the-art in 1959 was not compatible with anticipated Nike Zeus production requirements, the U. S. Army Signal Supply Agency, Philadelphia, Pennsylvania, modified PEM Contract No. DA-36-039-SC-72729. Modification No. 11 dated 30 April 1959 authorized the Western Electric Company, Laureldale, Pennsylvania to mechanize fourteen 2N559 production operations by providing 14 machines. Six of these operations were transferred to this Mechanization Program from the Device 12 Mechanization Program started 11 months earlier.

III Production Planning

Changes in Nike Zeus production requirements brought about several changes in initial production Planning before Phase 1 of the Contract ended on December 31, 1962. Figure 1-1 summarizes the changes in production planning effected by various Contract Modifications. In June 1959, the scope of the Contract was increased (1) by adding 2N1094 transistor production to the mechanization program and (2) by increasing the production capability of the mechanized line from 10,000 to 12,000 transistors per day without increasing the production requirements for mechanized Wire Bonding. The daily output of the Wire Bonding operation remained at 6,000. The number of mechanized operations and machines was increased to 21 in order to meet these requirements.

To meet the June 1960 production requirements, a balanced mechanized line concept was added to the Contract in July 1960. Under this concept, the production requirements were increased so that Wire Bonding as well as all other operations of the mechanized line had the capability to produce 12,000 good transistors per day or 60,000 per week. As a result of the increased requirements and mechanization developments during the preceding year, the number of machines was increased to 38. Twenty-four prototype machines were then contracted; 14 additional machines were also required for 9 of the 24 mechanized operations.

Since June 1960, Nike Zeus production requirements have changed twice and Nike Zeus development and testing have been extended. Recent contract modifications have adjusted machine requirements accordingly. The most recent modification as technically accepted December 1962 provides 25 machines. Only three additional machines will now be provided for two operations. The latest modification also extends machine development and refinement another two years, Phases 2 and 3.

Mechanization planning has compensated for reduced Zeus requirements by deleting additional machines and by increasing machine versatility. In one instance, machine development was discontinued because mechanization was no longer justified. With overall production requirements reduced it became practical to make certain machines more versatile and use them interchangeably for either 2N559-2N1094 production or for 2N560-2N1051-2N1195 production. Thus the present combined line concept evolved.

The mechanized equipment developed under this Contract and Contract No. DA-36-039-SC-81294 for high production of transistors is now combined into an integrated production line rather than two separated production lines envisioned previously. At the end of Phase 1, 10 of the 22 machines developed under this Contract can be used for 2N560-2N1051-2N1195 production and 8 of the 14 machines developed under Contract No. DA-36-039-SC-81294 can be used for 2N559-2N1094 production.

IV. Process and Design Changes

Several major changes in transistor design were made by the Bell Telephone Laboratories, Laureldale, during machine development. Initially, transistors were baked-out and backfilled with the desired ambient before sealing the tubulation. A one-piece can containing a moisture getter replaced this encapsulation. A welding procedure was then developed which provides the best possible ambient before welding the can to the header. See Section 3.16 for development of the Closure Welding operation.

Considerable product and machine development took place before the present Can Getter Assembling operatdon was established. This operation was conceived as a one-machine operation and is so listed in the

Contract; in reality, two major components, one minor component, and a sintering furnace are provided for this assembly operation. Section 3.10 reviews these developments and describes the components provided.

Early in the mechanization program 3-inch header leads were specified; on February 8, 1962, the lead length was decreased to 1-1/2 inches. This change affected several machines. An earlier header design change, butt-welding the collector lead to the platform was made June 1, 1961. This added a new machine to the Contract, eliminated mechanized Header Lead Trimming, and caused extensive modification to the Header Assembling Machine. The butt-welded subassembly introduced a major operational problem during prove-in and shop trial of the Header Assembling Machine.

One process development eliminated a wire handling problem on the Header Assembling Machine. This development eliminated wire oxidizing before Header Assembling and created the need for another machine, Header Glassing, which not only fuses the glass in the header platform but also oxidizes metallic parts before glassing. Initially, wire oxidizing was done immediately after wire cleaning on the Cleaning Header Lead Wire Machine and platforms were oxidized in an oxidizing furnace.

V Mechanization Developments

While the foregoing developments aided in attaining the Phase 1 production goals, simplifying operator's duties and minimizing manual transfer of piece parts and transistors were mainly responsible for increasing the production levels. To obtain efficient handling of piece parts and transistors, several handling systems were developed which are integrated with associated machines. In one instance, two Strip Perforating and Welding Machines were provided to assure proper header handling during the Header Continuous Rack Plating operation. Trays and magazines were developed to transfer large quantities of cans, headers, and wafers between associated machines while maintaining the desired orientation and header lead straightness. To make the tray handling systems reliable, both uniform wafers and headers with straight leads were required. The Slice Scribing Machine (Section 3.11) provides the uniform wafers. The Header Continuous Rack Plating Machine (Section 3.9) maintains the lead straightness required for subsequent assembly operations. The Cleaning Header Lead Wire Machine (Section 3.1) was needed not only to preserve lead straightness during cleaning but also to remove burrs which would interfere with lead loading during Header Assembling.

Efficiency has been increased considerably at the bottleneck operation - Wire Bonding - by utilizing Stitch Wire Bonding. This method provides an efficient means of continuously feeding .0005-inch-diameter wire to the bonding tip, and it eliminates elaborate wire preparations previously required. A number of special studies relating to Wire Bonding are reported in Section 5.

The handling system used for testing and packaging the 2N559 transistor was developed jointly by Western Electric Engineers at Laureldale, Pennsylvania, and Greensboro, North Carolina, and by the United Shoe Machinery Research Center, Xenia, Ohio, in order that the system would be compatible with a mechanized unloading machine on the user's production line. The system not only keeps the leads straight but is also very compact and inexpensive. Sections 3.17 and 3.20 review the development of the system and describe the machines needed to fabricate the system; description of the package is contained in the Material Handling portion of Section 2.

As noted previously, changes to the transistor design specifications by the Bell Telephone Laboratories influenced the scope of the mechanization program. In the actual performance of the Contract, Bell Telephone Laboratories contributed directly to the overall Western Electric Company effort by providing technical assistance to the mechanization program. This technical assistance, in the form of an engineering service during the development of the mechanized equipment, extended over the 3-1/2 year Phase 1 period of the Contract. Because the scope of this consulting service included a large number of areas, a separate narrative for the Laboratories effort is not feasible. Accordingly, the Bell Telephone Laboratories contributions have been integrated into the individual machine narratives and are not specifically indentified within the mechanization development programs.

PRODUCTION PLANNING FOR THE 2N559-2N1094 MECHANIZED LINE

MODIFICATION NO.	DATE	WEEKLY OUTPUT MECHANIZED LINE	NO. OF MACHINES PROTOTYPES	NO. OF MACHINES TOTAL
11	4/30/59	10,000[1]	14	14
12	6/25/59	12,000[1,2]	21	21
14	6/10/60	12,000	21	21
15	7/26/60	60,000	24	38
19	10/23/61	60,000	23	37
20	1/9/62	60,000	22	33
23	12/19/62	24,000 (Phase 1)	22	25
		60,000 (Phase 2)[3]	22	25

1. Wire bonding output 6,000 per week
2. Wafer bonding output 11,000 per week
3. To attain this output, additional duplicate machines will be required for certain bottleneck operations. These machines will be provided under Facility Contract No. DA-36-039-SC-26645 after prototypes are refined and updated only if a Nike Zeus order appears imminent or is placed.
4. Technical acceptance date

FIGURE 1-1

SECTION 2

MECHANIZED PRODUCTION LINE

D. H. Lockart

MECHANIZED PRODUCTION LINE

I General

The major requirement of Phase 1 of the 2N559-2N1094 mechanization portion of PEM Contract No. DA-36-039-SC-72729 is provision of high volume production equipment required to develop and install a limited production line capable of producing at least 24,000 transistors conforming to applicable specifications per two shift, eight hour, five day week. In addition to specific machines this capability includes the provision of associated tooling and facilities. To meet this requirement, an integrated production line capable of manufacturing 2N559 and 2N1094 transistors has been designed, fabricated and installed.

Normal practice requires that a pilot production run be made over a manufacturing facility to verify machine performance and line capability. In this case, however, a pilot run was not made a requirement under the PEM contract for the following reasons. During the Phase 1 period of the Contract, the Western Electric Company's North Carolina Works was authorized to develop a production capability for inserting 2N559 transistors into certain Nike Zeus equipment components. This authorization was made under the terms and conditions of Government Contract DA-30-069-ORD-3100. One of the sub-items under this contract called for a pilot production run, which, in turn, required completed 2N559 transistors. As a result, an Interworks Order was issued for a total of 42,000 completed 2N559 transistors meeting the applicable specification to be produced on the mechanized production line. Authorization was given in the same order to produce an additional 3,000 devices to be used in a reliability evaluation of 2N559 transistors manufactured on the mechanized production line. This interworks order, therefore, provided the authorization for the 45,000 unit pilot production run made over the production line.

During the period covered by the 2N559 pilot production run, 2N560, 2N1051, 2N1094 and 2N1195 transistors were processed over the mechanized line using all equipment capable of processing these codes. These devices were used to meet the test data requirements of the Contract. After test parameter readings were obtained, these devices were shipped as regular product, so manufacturing costs were not absorbed by either the PEM Contract or the interworks order. Data collection costs were, of course, borne by the Contract.

II Mechanized Line Operations

Phase 1 of PEM Contract No. DA-36-039-SC-72729 limited the development of high volume production equipment to specific quantities and types of machines and tooling. It was not intended that all manufacturing operations be mechanized, but that machines would be built for those operations and processes which could be made more reliable or required a high degree of skill by the operator. As a result, the limited production line is a "hybrid" line consisting of a mixture of mechanized and unmechanized equipment.

For purposes of this discussion the subject production line is divided into four parts as follows:

1. Transistor Header Assembly
2. Semiconductor Material Preparation
3. Transistor Can Assembly
4. Transistor Assembly

Each part will be discussed in sufficient detail to provide an understanding of the relationship of the various items of mechanized equipment to the unmechanized operations and the production line as a whole.

The transistor header assembly portion of the production line is highly mechanized. Machines have been provided to perform most of the critical operations. A header assembly requires one platform, two electropolished leads, one cleaned lead, one piece of cut glass tubing and one piece of cut glass rod. Cleaning and drying of the platforms and the cleaned lead is done by the Piece Part Cleaning Machine, Item 6-2-2 of the contract. The purpose of this cleaning is to remove greases, oils, and oxides from the surfaces of the parts. Cleaning of the glass parts is done on a batch basis by manually rinsing in cleaning solutions. The two electropolished leads are processed over the Cleaning Header Lead Wire Machine, Item 6-2-1. This machine cleans only that portion of the leads which is involved in the glass-to-metal seal during fabrication of the header. Cleaning is accomplished by removing a layer of the lead by electropolishing. Rinsing and drying are also done by the machine.

Following cleaning and drying of the platform and the cleaned lead, they are butt-welded together in the Platform Lead Welding Machine, Item 6-2-4 of the Contract. The lead becomes the collector lead of the transistor and the platform will subsequently support the semiconductor material used in making the transistor. The lead is welded to the underside of the platform properly positioned with respect to the platform locating tab. Following welding, the assemblies are decarburized on a batch basis in a furnace with an atmosphere of wet dissociated ammonia.

Assembly of the various header piece parts is done by the Header Assembling Machine, Item 6-2-5. Initially, the collector lead-platform subassembly is manually placed in proper orientation in a ceramic mold which will be used during the subsequent glass-sealing operation. These molds each containing 12 subassemblies are fed into the Header Assembling Machine where the base and emitter leads (the electropolished leads) and the pieces of glass rod and glass tubing are automatically fed and placed in proper position. The final station of this machine bends the emitter and collector leads of each assembly and welds all three leads together. This step is taken for the following reasons. The emitter and collector leads are bent to separate them from the center base lead during gold plating. If the leads are too close together during this operation, a "shadowing" effect is noted, which results in little or no plate on the inner surfaces of the leads. The leads are welded together to strengthen the structure, which helps prevent bending of the leads during subsequent handling. Automatic insertion of headers into the various machines is made easier with the leads joined together.

After assembly the loaded molds are processed through the Header Glassing Machine, Item 6-2-6. This machine oxidizes the metal piece parts in the assembly and melts the glass parts, thereby forming a glass-to-metal seal between the glass and the platform and the glass and the leads. Annealing of the sealed header is also completed in this machine. Following glassing, parts are manually unloaded from the molds and inspected for lead location, for proper welding of leads, and for glass height above the bottom of the platform.

Assembled headers are manually fed into tooling which trims the two ungrounded leads, namely, the base and emitter leads to the proper height with reference to the bottom of the platform flange. After trimming the headers are returned to the Piece Part Cleaning Machine, Item 6-2-2, where oils, oxides and excessive glass are removed. After this operation a 100 percent inspection for glass defects is made. Next the headers are chemically cleaned, polished, rinsed, and dried in batch amounts using various tanks and commercial dryers. The purpose of this operation is to remove oils and greases present on the headers due to handling and to prepare the metal surfaces by etching for gold plating.

After cleaning and polishing the headers are processed to the Strip Perforating and Welding Machine, Item 6-2-8. This machine punches index holes into a steel tape and welds the ends of the header leads to the tape. The tape containing the headers is wound on a reel for processing to gold plating. Plating is done by the Header Continuous Rack Plating Machine, Item 6-2-9. Reels of welded headers are unwound and the strip is drawn through various cleaning, rinsing, plating and drying stations. Gold plated headers are then sheared from the strip in a manner not affecting the weld between the three leads. After strip plating, headers are sintered in batch quantities in a commercial furnace.

Plating inspection and a final inspection of a random sample of completed headers prepares the headers for shipment to the transistor assembly area. A flow diagram of the operations entailed in manufacturing transistor headers is shown in Figure 2-1.

Preparation of semiconductor material starts with the basic raw material, germanium dioxide, and ends with inspection of completed wafers. No machines have been fabricated for processing of the basic material since most of this processing is done with large quantities. It is not until the material is ready to be broken down into wafers that mechanized equipment can be justified. The various operations involved in material processing will not be discussed in detail. Essentially the material is reduced to germanium metal, zone refined, and zone leveled. Zone leveling provides for the introduction of doping alloys and for the growing of a single crystal. The single crystal bar is cut into slices and the resultant slices are lapped and etched on both sides and mechanically polished on one side. Polished slices are transported to the gaseous diffusion process where the semiconductor junction is formed.

The "P" type germanium slice used in manufacturing the 2N559 transistor is diffused with antimony to form an "N" skin on its surface. Since the "N" skin is formed on all external surfaces it must be subsequently removed from the unpolished side by etching. After a clean-up etch a copper backing is evaporated onto the unpolished side of the slice. Following an additional clean-up etch, gold and aluminum base and emitter stripe pairs are evaporated onto the polished side of the slice. The aluminum emitter stripes are permitted to alloy into the germanium slice forming a "P" region in the "N" skin.

The active area of the 2N559 transistor wafer is surrounded by a moat deep enough to penetrate through the "N" skin into the "P" region. This moat is formed while the material is still in the slice form by use of an ultraviolet light-sensitive material, suitable masks and etchants. This process forms a physically undamaged active area with the evaporated stripe pair in the center.

Following the moating process the semiconductor slice is scribed for subsequent breaking into wafers by the Slice Scribing Machine, Item 6-2-11 under the Contract. Scribe lines are cut with a diamond point on .020-inch centers in both X and Y directions. After cleaning to remove chips and dust the scribed slices are fed to the Wafer Breaking, Screening and Loading Machine, Item 6-2-12. In this machine the slices are broken into wafers, the wafers are screened for defects and, if acceptable, are loaded into wafer handling trays. These loaded trays form one of the inputs to the transistor assembly portion of the mechanized line. A flow diagram of the operations entailed in processing semiconductor material is shown in Figure 2-2.

This metal can which is used to enclose the assembled transistor is formed on a punch press using tooling developed under the PEM Contract. After proper cleaning to remove oils, greases and oxides, cans are fed into the Can Getter Assembling Machine, Item 6-2-10. This machine has two main sections. The Can Loading Section loads the cans into pallets and then places a measured amount of nickel powder into each can. A powder leveling component levels the nickel powder in the cans and places the loaded pallets on a moving belt of a sintering furnace. Following sintering the pallets are fed into the Getter Loading Section which removes any loose particles of sintered nickel, adds a moisture seeking getter, melts the getter and permits it to flow into the pores of the sintered nickel powder where it solidifies. The can getter assemblies are then processed through an activating furnace just prior to use. This furnace drives off the moisture present in the getter. Assemblies are stored in dessicator flasks under vacuum until used. The flow diagram of the operations affecting the can is included with the transistor assembly flow diagram, Figure 2-3.

The first transistor assembly operation is accomplished on the Wafer Bonding Machine, Item 6-2-13. Here the semiconductor wafer is intimately joined to the transistor header through the medium of a gold-germanium eutectic bond. Wafers are loaded into the machine in trays, each holding 100 oriented wafers. Headers are manually loaded into the machine during the dwell period of the operating cycle. Wafer bonded headers are automatically unloaded following which they are manually placed in magnetic handling racks for further processing. The wafer-header subassemblies are screened for bonding defects following which acceptable subassemblies are spray-cleaned to prepare the gold and aluminum stripes for wire bonding. Both the screening and the spraying operations are performed with the wafer bonded headers in the handling racks. The Wire Bonding Machine, Item 6-2-14, attaches gold wire to the gold and aluminum wafer stripes and to the portions of the transistor external leads extending above the header platform. The gold wire used is .0005 inch in diameter and is attached to the stripes and leads using a thermal compression principle. One span of wire is attached to the gold base stripe and the base lead. A second span of wire is attached to the aluminum emitter stripe and the emitter lead. Wire is presently being re-spooled before use in the Wire Bonding Machine, but it is anticipated that this re-spooling operation can be eliminated. Following wire bonding, loose ends of gold wire extending beyond the external leads are manually trimmed.

The next operation after gold wire trimming is Final Cleaning. This operation is performed by the Final Cleaning Machine, Item 6-2-15. Wire bonded transistors are lightly etched with hydrogen peroxide, rinsed with deionized water and partially dried with a methanol dip. Drying is completed in an infrared drying chamber. The purpose of the etching operation is to clean the transistor active area of greases and foreign particles. Immediately after etching, the devices are placed in a 300°C baking oven. This bake passivates the surface of the semiconductor material and stabilizes the electrical characteristics of the device. Following the 300°C bake, a protective coating of SiO_2, silicon dioxide, is applied to the top surface of the transistor and header. The purpose of this coating is to protect the transistor junctions from foreign particles. All devices after coating go into a 200°C pre-weld bake. This bake drives out any gases which may have been trapped by the silicon dioxide coating and also dries the coating itself by driving off any moisture.

After completing the pre-weld bake the devices are processed to the Closure Welding Machine, Item 6-2-16. In this machine the metal cans containing the moisture seeking getter are welded to the transistor headers in an atmosphere consisting of a mixture of nitrogen, oxygen and helium. The helium is used as a trace element during the next operation, helium leak detection. In this operation minute leaks through the weld, through the can or through the glass to metal seals can be detected by sensing the presence of helium in the atmosphere surrounding the device. Devices which pass this check are given a bake in an oven set at 250°C. This bake rapidly drives any moisture remaining inside the can into the getter.

Following the 250°C bake, devices are placed in a container filled with alcohol. The purpose of this operation is to allow the alcohol to penetrate any large leaks which may be present in the device.

The presence of alcohol in the device is detected at D-C Test #1 by the failure of the unit to meet leakage current specifications. The alcohol soaking operation is necessary since large magnitude leaks are not detected by the helium leak check. In this case, the helium is exhausted by the time the check is made.

Just prior to testing, the transistor leads are cut to final length. The weld holding the three external leads together is removed by this trimming. The completed transistors are then processed to D-C Test #1 where all Group A D-C Tests in the applicable specification are made on a go no-go basis. Good units after testing are cleaned to remove oils and greases following which the external leads are coated with solder. After a second degreasing the devices are processed to the Painting and Coating, and Coding Machines. These machines were developed under an associated PEM Contract No. DA-36-039-SC-81294 but are capable of processing SC-72729 Contract device types. Units are manually loaded into magnetic handling trays which are automatically fed into the Painting and Coating Machine for painting. Following this operation the devices are baked and then processed to the Coding Machine. Following coding, the devices are baked a second time and then processed to the Painting and Coating Machine again for varnish coating. A third bake follows coating. Devices remain on the magnetic handling trays throughout all of the above operations.

The completed transistors mounted on magnetic handling trays are manually fed into the Card Loading Machine, Item 6-2-17. This machine spreads the transistor leads, places the transistor on a pre-punched strip of black electrical cardboard, attaches the leads to the strip with heat-sealable tape, cuts the strip into individual cards and feeds the card-mounted transistors into the Testing and Date Stamping Machine, Item 6-2-18. This machine performs all Group A tests on the 2N559 transistor on a go no-go basis. Capability of stamping a three digit acceptance date on the top of the transistor can is also provided, however, this operation is presently being done at the same time as the remainder of the coding is applied.

Transistors passing this series of tests are submitted to a final inspection which is done on a sample basis. The various samples are submitted to electrical and environmental tests as determined by the applicable specification. All electrical tests associated with this inspection are performed on the Data Handling System, Item 6-2-19, which provides, in addition to test capability, data recording and processing capability. This system is also used for production control purposes and for semiconductor slice evaluation. If the transistor lot passes final inspection, the individual card-mounted transistors are placed on a

"Mylar" Shipping belt by the Card Packaging Machine, Item 6-2-20. This machine punches the "Mylar" belt according to the desired pattern and indexes the belt to a manual loading station. The loaded belt is automatically wound on a shipping reel by the machine. A flow diagram of all transistor assembly operations is shown in Figure 2-3.

All items of mechanized equipment have been included in the above resume with the exception of the Piece Part Gold Plating Machine, Item 6-2-3, and the Header Lead Trimming Machine, Item 6-2-7. These machines were made obsolete by process changes and are no longer used in the production line.

III Material Handling

Several unique material handling components were provided to support the various items of mechanized equipment developed under the PEM Contract. These components are used to support transistor elements either during the time they are in the machines, or during storage periods between operations or both. They are also used to maintain orientation of elements, to make handling easier, and to protect the elements from physical damage.

In this sub-section all material handling components developed under the contract will be described in detail. Illustrations have been included to help clarify these descriptions. The relationships of these various components to the contract machines will be emphasized.

The first material handling components used in header assembly are the ceramic molds used for receiving the header piece parts during assembling and for holding these parts during glass-to-metal sealing. These molds each have 12 cavities into which platform-lead subassemblies are manually loaded. A locating slot receives the tab on the header platform to provide proper orientation. At the base of each cavity two holes are drilled to receive the base and emitter leads as they are fed through holes in the platform by the Header Assembling Machine. A third hole is provided for possible automatic unloading of the molds after glassing. V-shaped slots are provided on one side of the molds for locating during header assembly. Each slot is relieved on one edge to provide for indexing the molds. The mold used for the TO-18 header is shown in Figure 2-4.

The next material handling component used in header assembling is the strip to which the headers are welded by the Strip Perforating and Welding Machines. The strip itself is made of steel and is used as a means of supporting the assembled transistor headers during gold plating. It also forms the electrical contact to the headers during plating. The headers are welded onto the strip on 1/4-inch centers using the extreme 3/32-inch portion of the leads. The three leads have been previously welded together on the Header Assembling Machine. Indexing holes are punched into the strip by the Strip Perforating and Welding Machine. These holes mate with the teeth in the drive wheels of the Header Continuous Rack Plating Machine. The strip is pulled and guided through the Plating Machine by the various drive wheels, thereby providing a means for passing the headers through various cleaning and plating solutions, rinsing stations and dryers. A picture of strip-mounted headers is shown in Figure 3.8-2.

Wafer trays and magazines were developed to support transistor wafers during the period of storage between the Wafer Breaking, Screening and Loading Machine and the Wafer Bonding Machine. Wafers are loaded into the trays automatically by the first machine and automatically unloaded from the trays by the second machine. During storage eight trays can be stored in one magazine. The trays have the capability of supporting the individual wafers, maintaining their orientation during reasonable handling, and providing some protection for the extremely small, brittle wafers. The magazines provide some protection from dust and contaminants settling directly on the surface of the wafers.

Each wafer tray holds 100 wafers of the .020 by .020-inch size, the size used for all contract codes. The wafers are held in square slots just slightly larger than the individual wafers. The wafer tray and magazine are illustrated in Figure 2-5. The wafer slots are the series of small squares along the centerline of the tray. The raised fins along the near side of the tray are used for indexing the tray during loading and unloading.

During the assembly of the transistor can and the moisture seeking getter in the Can Getter Assembling Machine, a metal pallet is used for supporting the transistor cans. This pallet is actually the handling medium of the machine itself. The first operation performed by the machine is the loading of 112 cans into each pallet. The cans remain in the pallets during all subsequent operations and are only unloaded after the operation is complete and the can getter assemblies are stored in dessicator flasks under vacuum. Between operations the pallets are stockpiled in pallet magazines, each magazine holding 18 pallets. The pallet with its accompanying magazine is shown in Figure 3.10-2.

The major handling component used in the transistor assembly line is a magnetic handling tray and magazine combination. This combination is first used as an output of the Wafer Bonding Machine. The wafer bonded headers are loaded into the magnetic tray and they remain in the tray during wafer bond inspection and spray cleaning. The trays are then used as the input to the Wire Bonding Machine. This machine automatically unloads the headers from the tray, performs the wire bonding operation and returns the headers to the tray. Following wire bonding the headers go to the Final Cleaning Machine. At this point they are transferred to a magnetic tray of a slightly different design. The tray used during final cleaning is the prototype design, and the Final Cleaning Machine design was based on it. It was not feasible to alter the Final Cleaning Machine to accept the new trays during Phase I, since transfer from one tray to another can be effected quickly and easily. Following final cleaning the headers are removed from the magnetic trays for further processing. Header tray magazines are used throughout the above-mentioned processes as storage for the loaded trays. They offer support and limited protection for the easily damaged devices.

Magnetic trays are used for input to the painting, coding and coating operations. Trays are automatically removed from the magazine, devices are mechanically removed from the trays, the operation is performed and the devices are replaced in the trays and the trays in the magazines. These steps are essentially repeated three times - once for each operation.

The magnetic trays are used again as the input to the Card Loading Machine. The trays are manually loaded into the machine, and the devices are automatically removed from the tray for card loading.

The magnetic trays each hold 30 units on 3/8-inch centers. The devices are held by attraction between the magnets and the metal external leads of the transistor. They are oriented so that the emitter and collector leads of the transistor rest against the magnet. In normal position the bottom of the transistor platform rests against the stainless steel plate which acts as a frame for the tray. For the wire bonding operation, the headers are pushed from beneath by a force applied on the welded lead ends raising the devices above the stainless steel plate.

The leads remain in contact with the magnet and are guided by slots cut in the plate.

Each magazine holds 20 trays for a total of 600 devices. Locks are provided to prevent the trays from sliding out of the magazines during handling. Trays and magazines are illustrated in Figure 2-6.

The Card Loading Machine mounts the transistors on cards for electrical testing and shipping. The leads of the devices are spread and held down on a belt of black electrical cardboard by means of a heat-sealable tape. The belt is cut into individual cards and the cards are fed into the 2N559 Testing and Date Stamping Machine. Only 2N559 transistors are handled in this manner. Good devices after testing remain on cards and are placed in a pre-punched "Mylar" shipping belt in the Card Packaging Machine. Both the card and the belt provide protection for the device and retain orientation of the external leads. Devices can be easily stripped from the cards for insertion into other machines or equipment. The card mounted transistor and the "Mylar" belt are illustrated in Figure 2-7.

During Phase 2 of the Contract material handling will be further evaluated to possibly extend it to other operations. Effort will be applied to eliminate manual loading of material handling components.

IV Pilot Production Run

The pilot production run, as mentioned earlier in this section, was based on an output of 45 thousand 2N559 transistors conforming to the applicable specification, in this case, MIL-S-19500/152A dated 22 May 1962. The purpose of the run was fourfold: first, it made completed 2N559 transistors available to Western Electric's Greensboro, North Carolina Plant for use in prove-in of their mechanized equipment;

second, it formed the basis for acceptance by the U. S. Army Electronics Materiel Agency of the PEM Contract mechanized equipment and manufacturing capability; third, it permitted studies and evaluation of new manufacturing processes and equipment plus a thorough evaluation of device reliability; fourth, completed devices were used to fulfill the PEM Contract commitment for submission of test data from nine thousand 2N559 transistors manufactured with the PEM equipment.

The subject pilot run started on September 5, 1962, with production of transistor headers. Machines and associated equipment connected with header manufacturing were operated as required until January 31, 1963, when all header shipping requirements were fulfilled. Assembly of transistors started on October 12, 1962 and was completed on March 14, 1963.

Several normal and anticipated problems arose and were met during the pilot run. Operators of the various items of mechanized equipment required training over and above that given during shop trial and/or production trial phases. Machines experienced periods of down-time due to maintenance requirements and due to the need for minor changes and adjustments. Variations in semiconductor material and piece parts were found which adversely affected the operation of some of the mechanized equipment. As anticipated, all transistor elements must be made with as little variation as possible, since the mechanized equipment will not accept wide fluctuations in parameters. All the above conditions contributed on occasion to delays in the pilot run, but all shipping schedules were fulfilled on time.

In general, the results of the pilot run met all expectations. Machinery functioned well considering the fact that almost all items of mechanized equipment are prototypes. Operators developed fast and became very skilled in operating the equipment. Operator errors did occur on occasion, but, fortunately, they were limited in number. No problems arose during the run which could not be solved within a reasonable period of time. Pilot run experiences on specific items of mechanized equipment are discussed in the individual machine sections of this report.

The PEM Contract requires that test data be provided on 250 each of 2N560, 2N1051, 2N1094 and 2N1195 transistors in addition to the test data on nine thousand 2N559 transistors mentioned earlier. During a portion of the 2N559 Pilot Run, devices to be used in providing this test data were processed over the mechanized line. Those machines capable of processing these other codes were used in this mechanized production run. After test data was accumulated, the acceptable devices were shipped as normal production.

V Test Data

Complete data on all Military Specification Group A parameters for the number and types of transistors specified in the Contract was accumulated and submitted to the U. S. Army Electronics Materiel Agency. The number and types of transistors and the number of parameters involved are listed below:

Device Type	Number of Devices	Number of Parameters
2N559	9,000	11
2N560	250	10
2N1051	250	9
2N1094	250	15
2N1195	250	11

The applicable military specifications for these devices are listed next:

Device Type	Applicable Specification
2N559	MIL-S-19500/152A dated 22 May 1962
2N560	MIL-S-19500/73A dated 29 July 1960
2N1051	MIL-S-19500/216(NAVY) dated 9 November 1961
2N1094	MIL-S-19500/161(SigC) dated 9 December 1960
2N1195	MIL-S-19500/71C dated 17 January 1961

In order to make the raw test data more understandable, distributions of parameter values were plotted. In the case of the 2N559, rather than making distributions of 9,000 values, a representative random sample of 500 devices was used. For all other codes, the contract requirement of 250 devices was used.

The distributions of the various parameter values are shown in Figures 2-8 to 2-63 inclusive. The device type, the test parameter, bias conditions, specified maximum and/or minimum test values, and the number of devices in the distribution are given for each figure.

The ordinate of each distribution shows the central values of the cells selected for plotting the distribution. For example, the I_{EBO} distribution for the 2N559 transistor, Figure 2-8, lists values of .100, .300, .500, etc. The first cell includes values from .000 to .200, the second cell includes values from .200 to .400, and so on. In the event a reading is obtained which coincides with the boundary value between two cells, for example .200, this device will be counted in the lower valued cell, the .100 cell.

Cell widths and the number of cells used have been selected on the basis of providing the most meaningful distributions. In doing this, it became impractical to list all the cells required to show the position of all units since the test values on certain devices show considerable departure from the norm. HI and LO categories were added to pick up these devices. These categories do not indicate "out-of-spec" devices, since all units used in accumulating the data met the applicable specifications.

It should be noted that leakage current (I_{CBO}) distributions for the 2N560 and 2N1051 contain several devices with readings of .0000 uAdc. The actual test values are not zero but are smaller than the minimum readout capability of the test equipment used in generating the data. These devices fall in the LO cell for that particular parameter.

Transistors are stockpiled after Group A final testing and submitted to final inspection on a lot basis. The final inspection organization takes random samples of the device lots and subjects them to the various Group B tests. In certain cases the test is an examination of the physical characteristics of the sample. A check of the dimensions of the completed transistors is an example of this case. In other tests, the sample is subjected to certain environmental conditions, following which the devices in the sample are subjected to end point electrical tests. Moisture resistance evaluation is an example of this latter type of Group B test.

The 2N559 Pilot Run production was divided into three lots for purposes of final inspection and shipment. The first lot contained approximately 9,000 devices, the second lot contained approximately 13,000 devices and the third lot was made up of approximately 20,000 devices. The results of the Group B evaluations of these three lots are given in Figure 2-64. Test conditions and limits are given in the applicable specification for the device.

The mechanized production lots from which the 2N560, 2N1051, 2N1094 and 2N1195 transistors used for data collection were taken were also submitted to Group B inspection. The results of these inspections are given in Figures 2-65, 2-66, 2-67, and 2-68.

VI Evaluation

Evaluation of the degree of success obtained in providing a mechanized production facility meeting the terms and conditions of the PEM Contract can best be made by considering the results of the 2N559 Pilot Run and the mechanized runs of the other codes. These runs essentially represented an opportunity to evaluate the performance of the individual machines, the contributions of the unmechanized processes to the various device parameters, the ability of the various material handling components to perform their particular functions, and the results of testing and final inspection of the completed transistors.

All runs made were basically successful. While many problems arose, none were of sufficient magnitude to require complete termination of production. The experience of these runs, however, dictates that certain safeguards be established to insure that transistors can be manufactured at the required production rate. These safeguards are listed below:

1. Skilled operators with the ability to use good judgement should be used. These operators should be thoroughly familiar with the operation of their machines or equipment.
2. Quality control measures should follow all operations which affect the product in any way. High capacity production lines are particularly vulnerable to variations caused by machine maladjustments or operator error.
3. Critical operations, whether mechanized or partially

mechanized, should be controlled automatically, whenever possible, rather than being placed under operator control.

4. Special efforts should be made to insure that all piece parts meet specifications consistent with mechanized production. Effort should also be applied to insure that all variables are covered by specifications.

These safeguards are not unique, since they should be a part of any production line. It is important, however, that they be enforced and continually checked for improvement particularly when applied to high-volume production lines. Most of the mechanized equipment developed under the PEM Contract was operated for the duration of the pilot and mechanized production runs. The performance of these machines is discussed in detail in the various individual machine reports. In summary, a list of the machines developed under this contract together with the Western Electric Company drawing numbers and the operating and maintenance specification numbers for the machines is given in Figure 2-69.

The distributions of the electrical test values for the various transistor codes shown in Figures 2-8 to 2-63 are normal bell-shaped distributions for the most part. Those distributions which depart from normal are discussed in the next few pages.

Figure 2-9, the BV_{EBO} distribution for the 2N559 transistor, shows that the specification limit of 5.0 volts minimum cuts away the lower portion of the distribution. This is caused by the diffusion cycle used which is fixed to optimize the gain of the device at some sacrifice in BV_{EBO} characteristics. Figure 2-11, the BV_{CES} distribution for the 2N559, shows a sharp drop on the upper end of the distribution. This drop is due to the inherent characteristics of the germanium material. The diffused collector to base junction breakdown voltage limits the upper values of BV_{CES}. The spreading of the lower values of the distribution shows the effects of emitter alloying. This spreading is a function of the variation in effective base width which is inversely proportional to emitter depth.

The h_{FE} distribution for the 2N559 transistor, Figure 2-15, is cut off sharply at the lower value end. Devices with low gain characteristics are rejected on the pulse response rise time test, which eliminates them from the distribution, since only good devices on all parameters have been used. The large spread of the pulse response storage time test values for the 2N559, Figure 2-18, is a result of the large spread of gain values shown in Figure 2-15. The two parameters can be correlated as will be noted by the approximately 4:1 spread of the values of each.

The BV_{CES} distribution for the 2N560 transistor, Figure 2-20, shows the same sharp drop on the upper end and the same spreading of the lower values as was shown in Figure 2-11 for the 2N559. The reasons for these conditions are also the same, namely, the inherent characteristics of the silicon material and the effects of emitter alloying. The h_{FE} distribution for the 2N560 transistor, Figure 2-24, also exhibits a sharp cutting away of the lower values. These devices were rejected on the various pulse response time tests and are, therefore, not included.

Figure 2-25, which shows the pulse response turn-on time values for the 2N560, exhibits the phenomenon of "operator favorite value". While the distribution is normal, certain values of turn-on time are favored by the operators taking visual readings from a meter. This results in certain cells containing a disproportionate number of devices while adjacent cells contain fewer than normal devices. Other distributions will exhibit this phenomenon when manual test readings are taken.

The BV_{CES} distribution for the 2N1051 transistor, Figure 2-31, shows the same sharp drop on the upper end as the 2N559 and 2N560 distributions for this parameter due again to the inherent limiting effect of the silicon material. In addition, another effect is noted. The distribution is bimodal which is caused by oscillations in a portion of the transistors tested. These oscillations produce a reduced BV_{CES} reading. The oscillations are caused by the external circuitry providing a feedback loop. Since these devices were tested, a special socket has been designed which eliminates this problem.

Figure 2-33, the V_{CE}(sat) distribution for the 2N1051 shows an abnormal gap in the 1.950-volt cell. It appears that there was a malfunction in the digital comparator of the test equipment at the time these tests were made. This malfunction, it is believed, caused an eight to be printed as the second digit even though a nine was indicated. Otherwise the distribution appears to be normal.

The h_{FE} distribution for the 2N1094 transistors, Figure 2-42, shows a sharp drop on its lower end. The devices whose gain values would normally have fallen in these cells have been eliminated on the noise figure, NF, test. The h_{fb} test for the 2N1094, Figure 2-44, shows an abnormal curve which peaks near the specification limit of 1.0. This is essentially an injection test and the only criterion is that h_{fb} does not reach unity. Heating of the device during testing tends to increase the value of h_{fb} and give the distribution a skewed effect.

Figure 2-46, the h_{rb} distribution for the 2N1094 shows several gaps. These gaps are due in part to the operator favorite value phenomenon since these readings were taken manually. In addition, it is necessary for the operator to change read-out scales from time to time. When this occurs, if the scales do not correspond exactly, it is possible that values near the extremes of the scales cannot be read. This condition also appears to be present in the h_{ib} distribution for the 2N1094, Figure 2-47.

Several distributions for the 2N1195 transistor require comment and evaluation. Figure 2-56, which shows the h_{fb} distribution peaks near the high specification limit and then drops off very sharply. This is due to the fact that electropolished germanium slices were used to fabricate the wafers used during the mechanized run for this device. Mechanically polished slices result in a normal distribution for this parameter. Figure 2-57, the C(dep) distribution for the 2N1195 is cut off very sharply by the maximum limit of 1.5 micro-microfarad. During the mechanized production run over-size slice moating masks were inadvertently used which resulted in larger than normal active areas. This condition directly affects this parameter. The problem has been corrected and C(dep) distributions are now normal.

The REh_{ie} distribution for the 2N1195, Figure 2-61, is cut away on its upper side by the 80-ohm specification limit. The diffusion cycle for this transistor is peaked to give a better BV_{EBO} distribution, Figure 2-55, which has this detrimental effect on REh_{ie}. The BV_{CEO} distribution for the 2N1195, Figure 2-63, is cut away on its lower-valued end by the specification limit of 20 volts. This is due to the use of electropolished slices as mentioned earlier. Use of mechanically polished slices causes this distribution to peak 2 to 3 volts higher.

All distributions which depart from normal can be attributed to assignable causes. Yields which resulted from the pilot run and from the various mechanized production runs are not discussed in this report since they are considered proprietary data by the Western Electric Company. These yields, however, when corrected for various known and assignable differences, were normal for this type of operation.

Evaluation of Group B inspection results indicates that all lots tested behaved in normal fashion. In no case were the allowable number of failures exceeded for any examination or test. In only three cases were the allowable number of failures equaled. 2N559 Lot Number 185P had two units fail Subgroup 4. This was probably a result of variations in wire bonding reliability during the early part of the pilot run while operators were still gaining experience and the process was being optimized. 2N559 Lot Number 188P had three units fail Subgroup 7. One of these failures turned out to be a testing failure destroyed during end point testing. The other two were devices whose leakage current readings shifted slightly out of limit. This, it is felt, represents a normal result for 2N559 Group B inspection. 2N1051 Lot Number 82 showed two failures on Subgroup 2. This was a result of a change in the shop testing limits for this device. During the period that Lot 82 was being processed, a new semi-automatic test set was introduced which was set up with test limits closer to the specification limit than formerly used. The two failures just barely failed the specification limit for the subgroup.

While the mechanized production line is a reality and has been operated in production, it is not claimed that all machines are problem-free or that all processes are optimized. Considerable effort is planned for Phase 2 of this Contract to update certain machines and to refine certain processes. Additional mechanized production runs will be made at the end of 1963 to evaluate the progress made during this phase.

VII Conclusions

The following conclusions are gathered from this report:

1. A mechanized production line consisting of prototype machines and associated tooling and facilities with a capacity meeting contract requirements has been provided.
2. A 2N559 pilot run and 2N560, 2N1051, 2N1094 and 2N1195 mechanized production runs were made on the mechanized line. These runs resulted in an output of good transistors meeting the applicable specifications. As proved by these runs, the line can be operated and will produce good product.
3. Distributions of test parameter values for all codes are normal with certain exceptions for which there are known assignable causes.

HEADER ASSEMBLY OPERATIONS

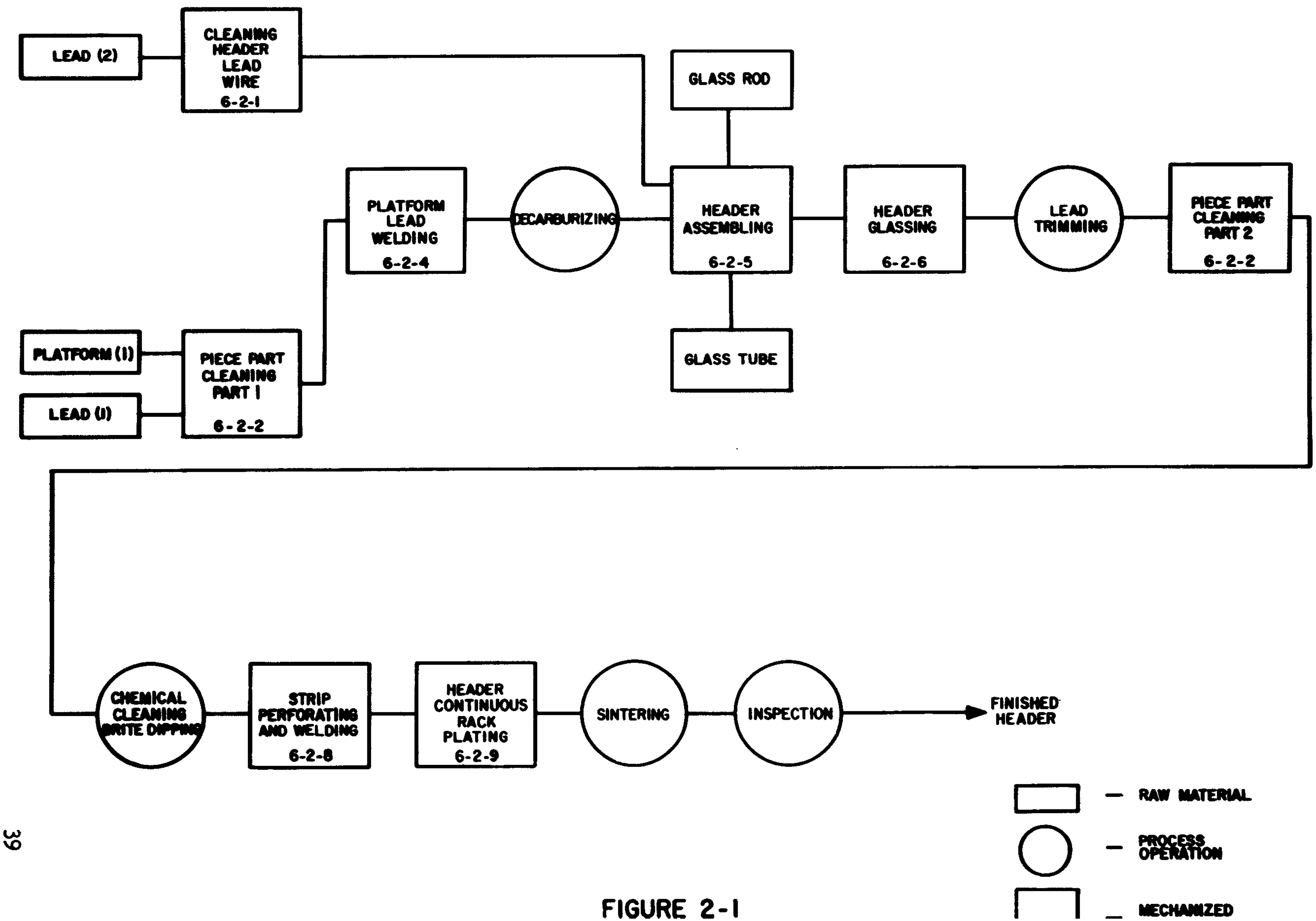
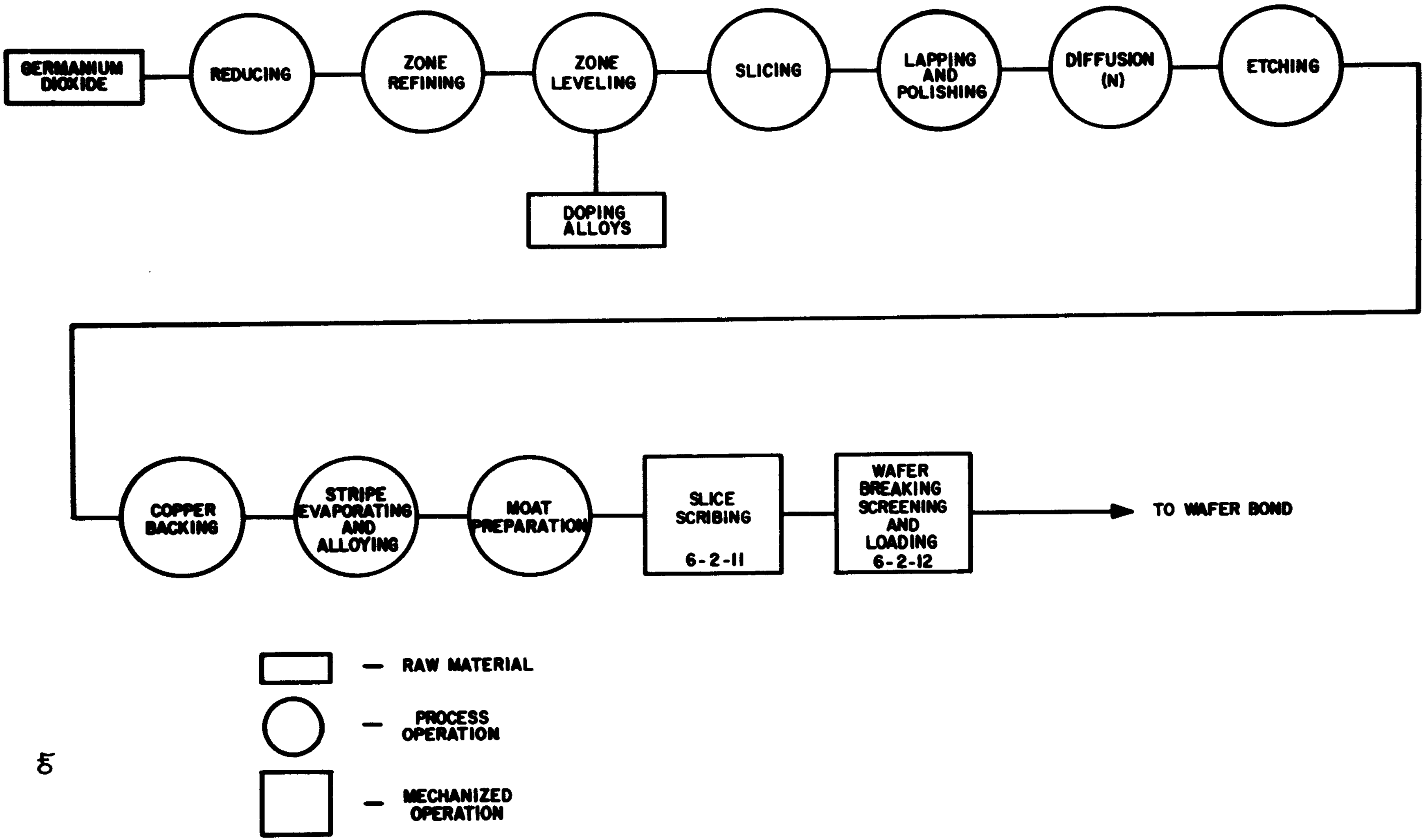
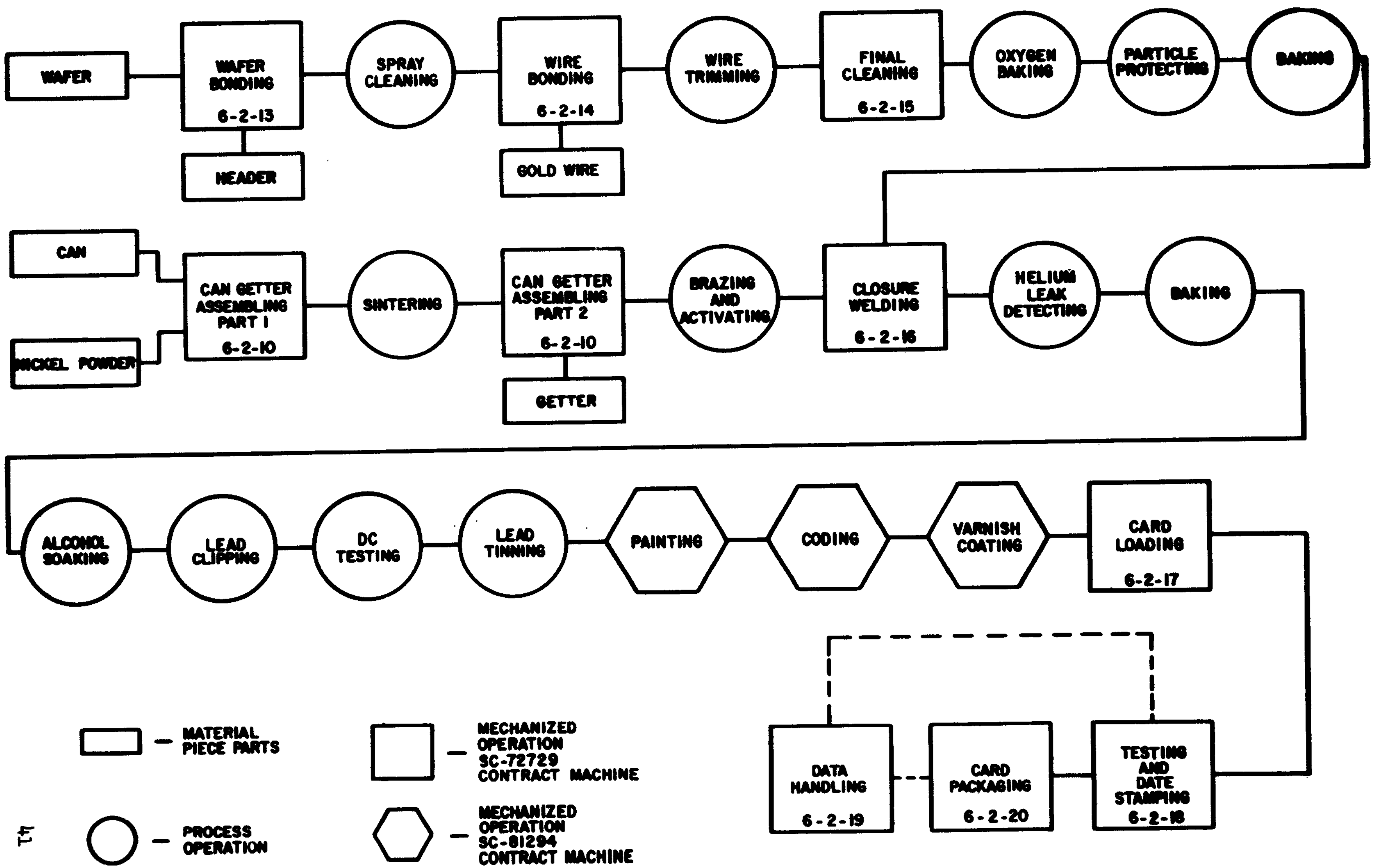


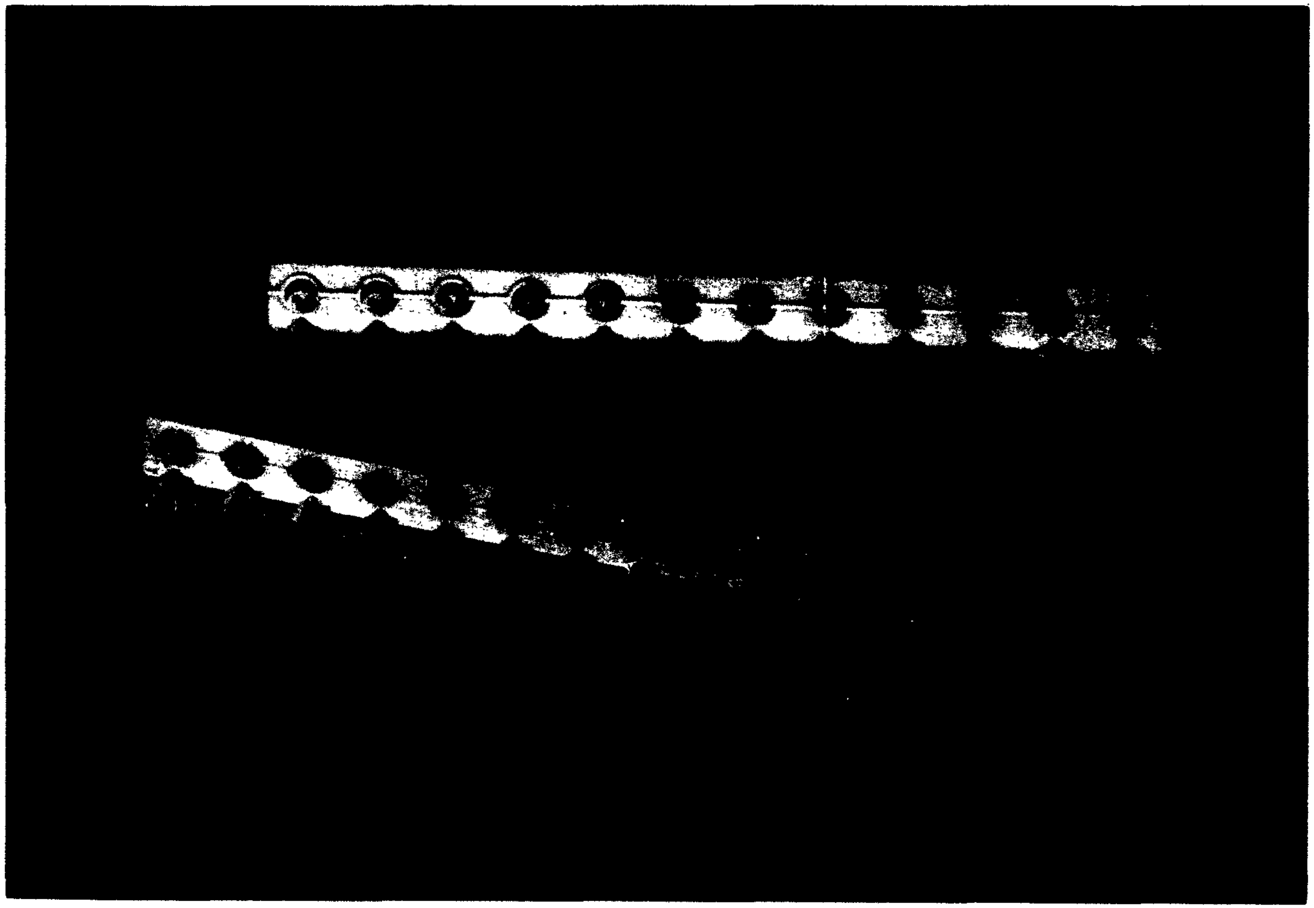
FIGURE 2-1

GERMANIUM MATERIAL PROCESSING

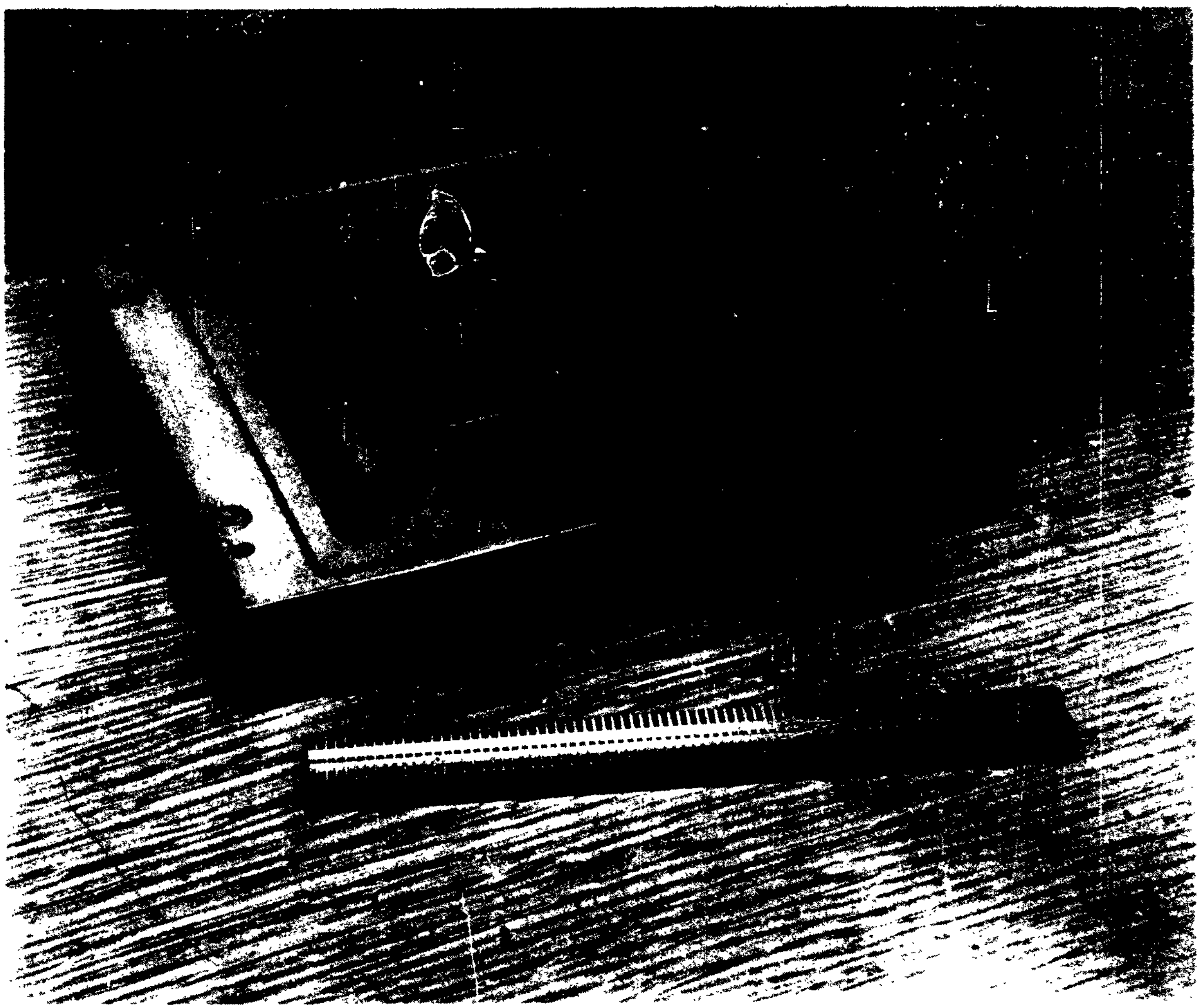


TRANSISTOR ASSEMBLY OPERATIONS

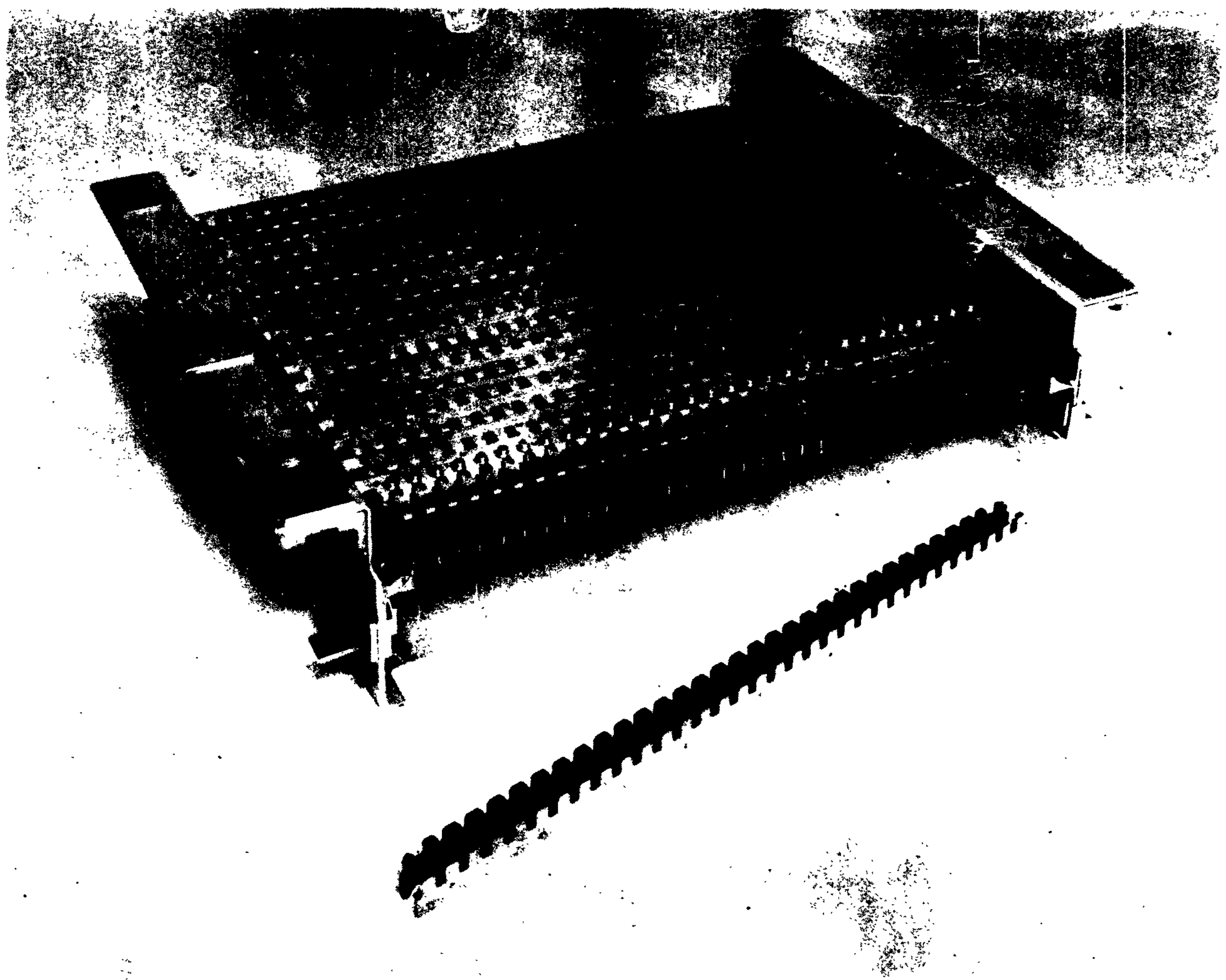




TO-18 HEADER GLASSING MOLDS
FIGURE 2-4



WAFER TRAY AND MAGAZINE
FIGURE 2-5



TO-18 HEADER TRAYS AND MAGAZINE
FIGURE 2-6

PACKAGED 2N559 TRANSISTOR
FIGURE 2-7

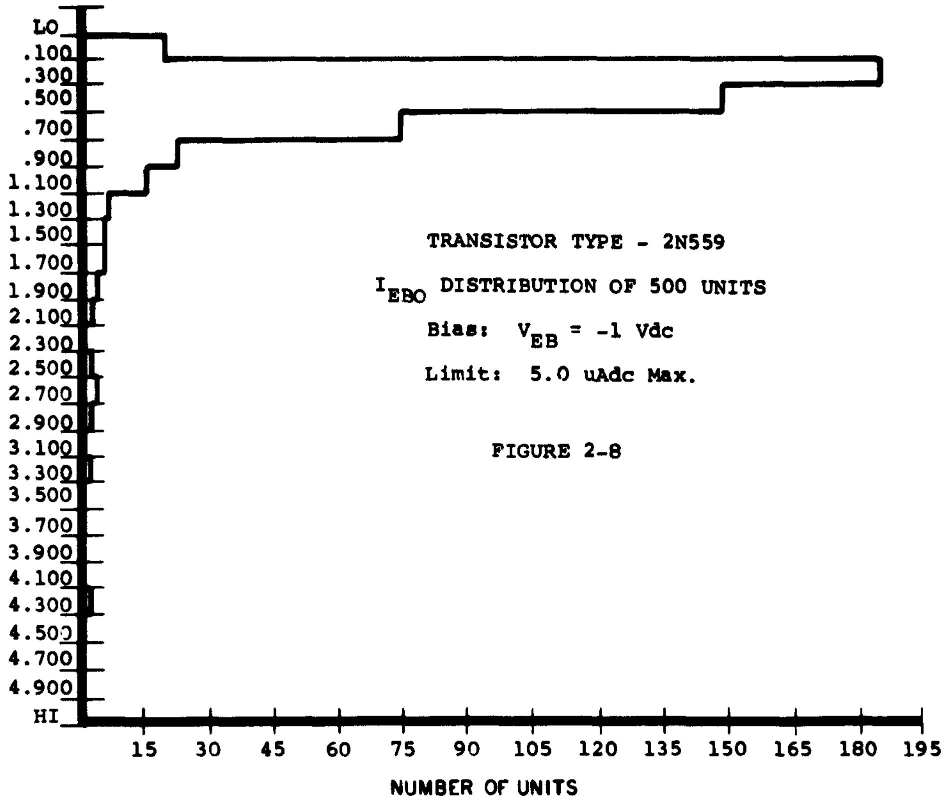


FIGURE 2-8

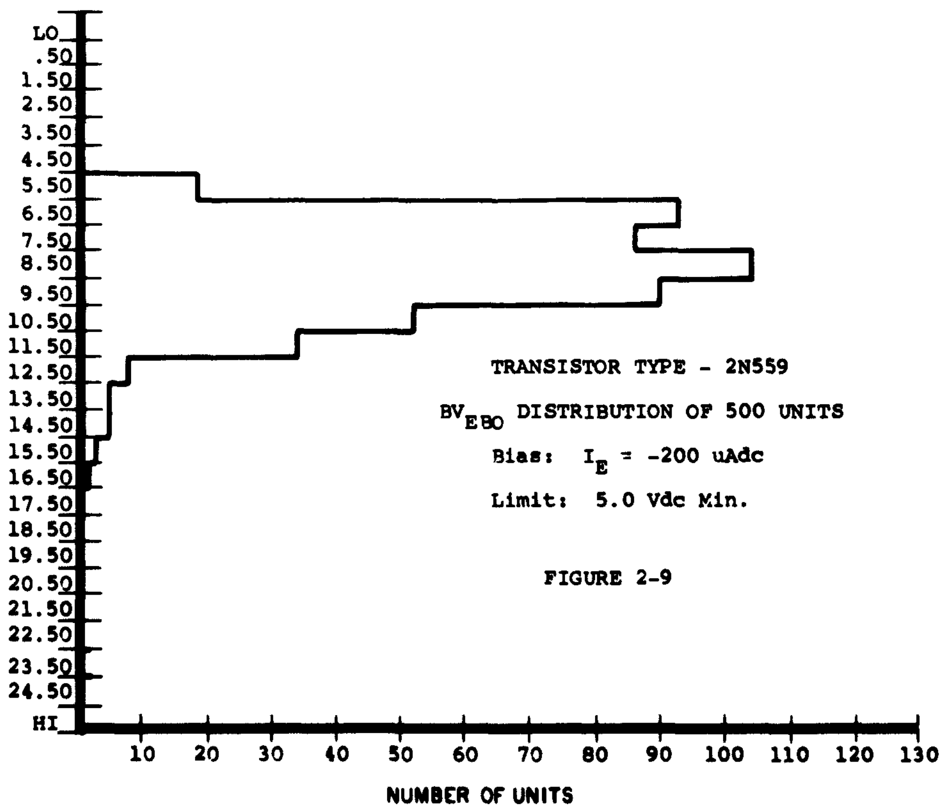


FIGURE 2-9

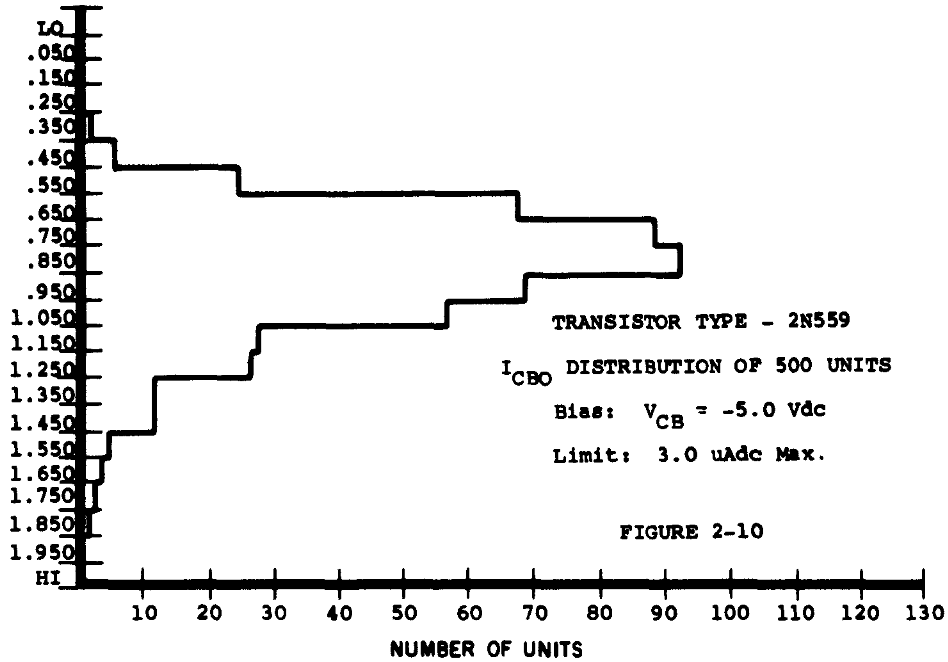


FIGURE 2-10

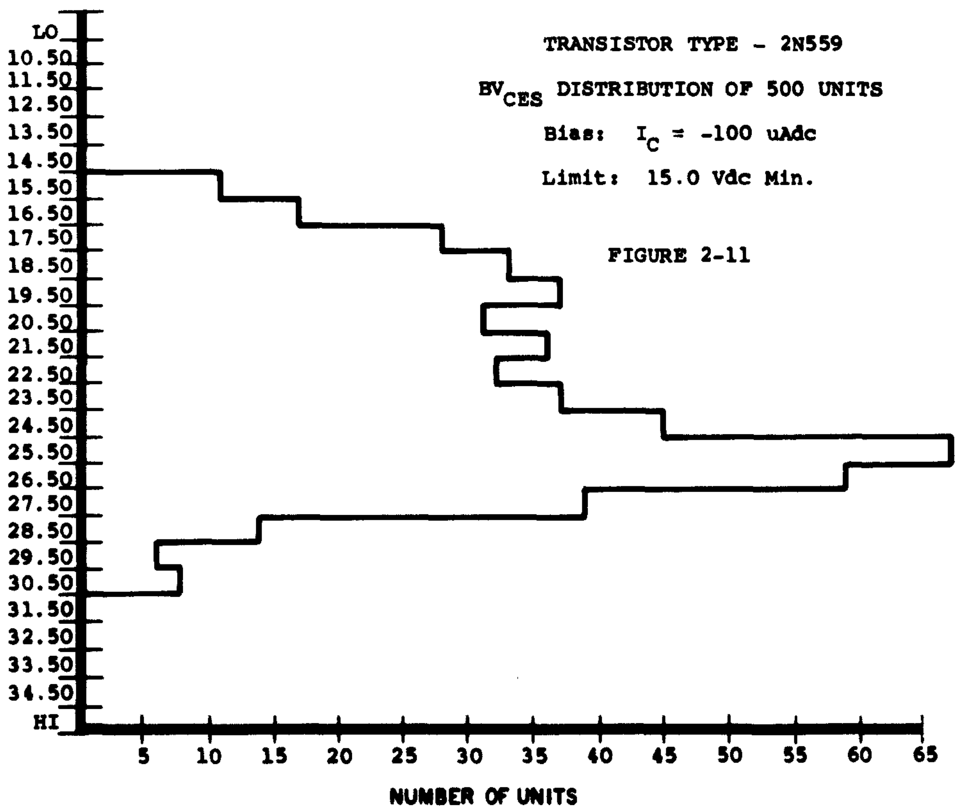


FIGURE 2-11

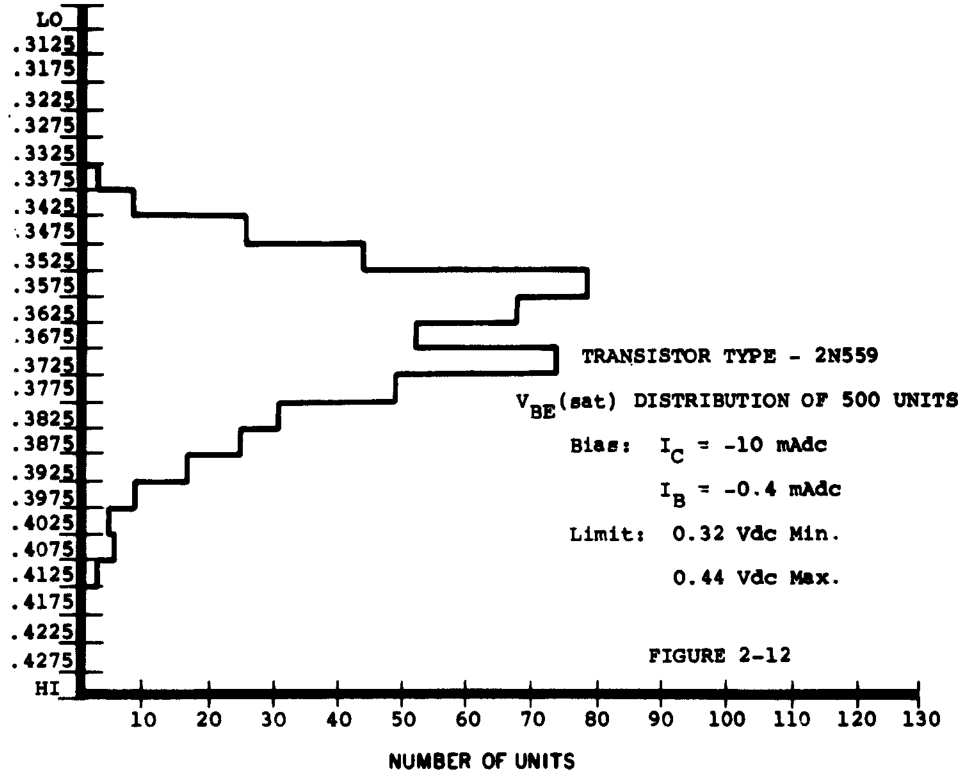


FIGURE 2-12

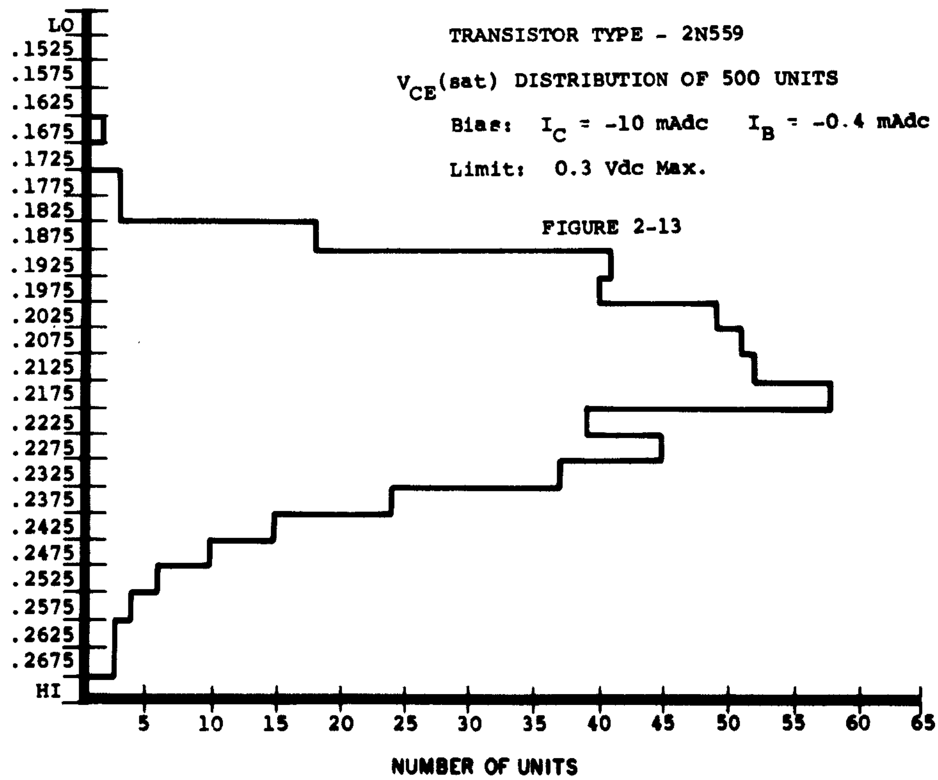


FIGURE 2-13

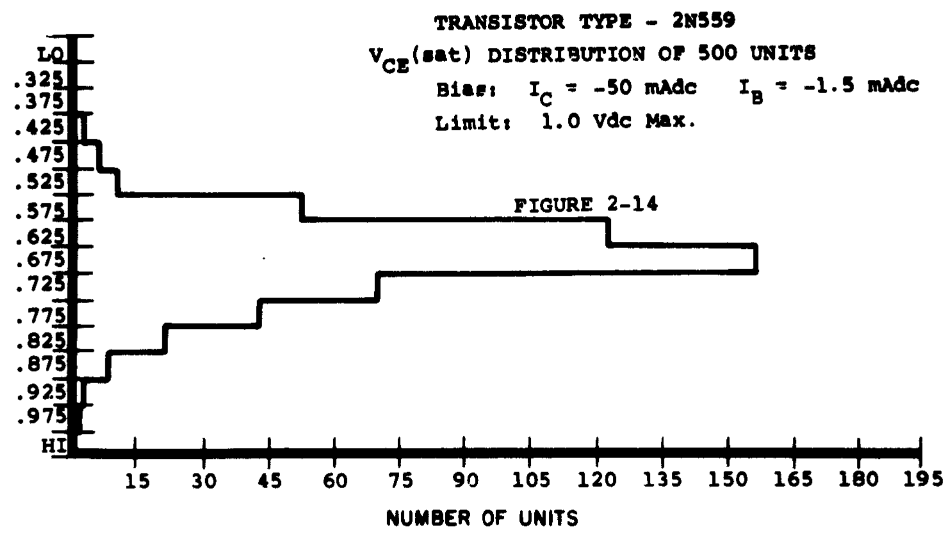


FIGURE 2-14

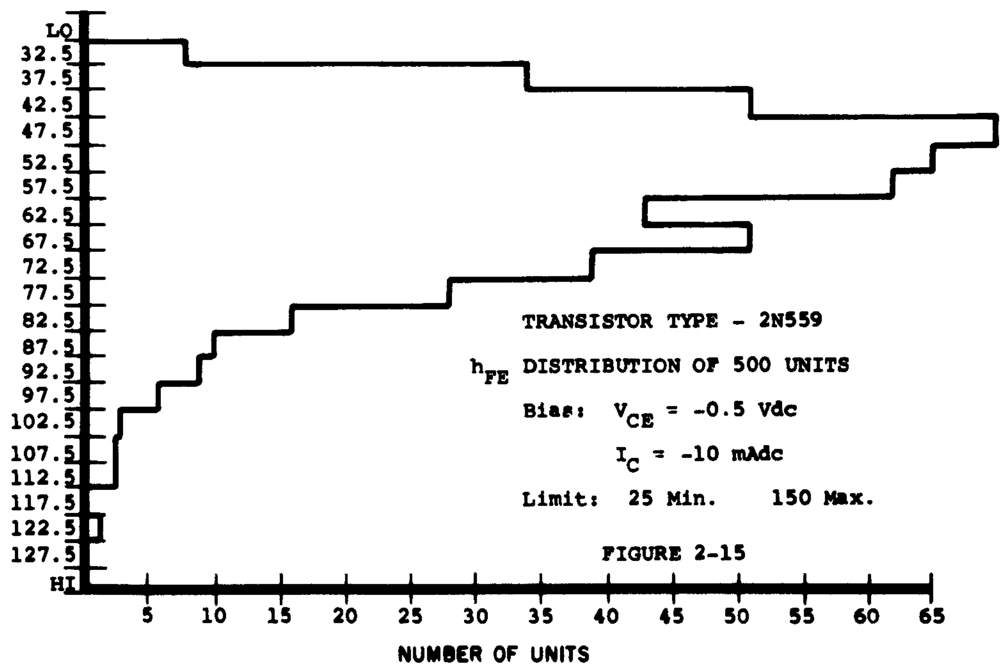


FIGURE 2-15

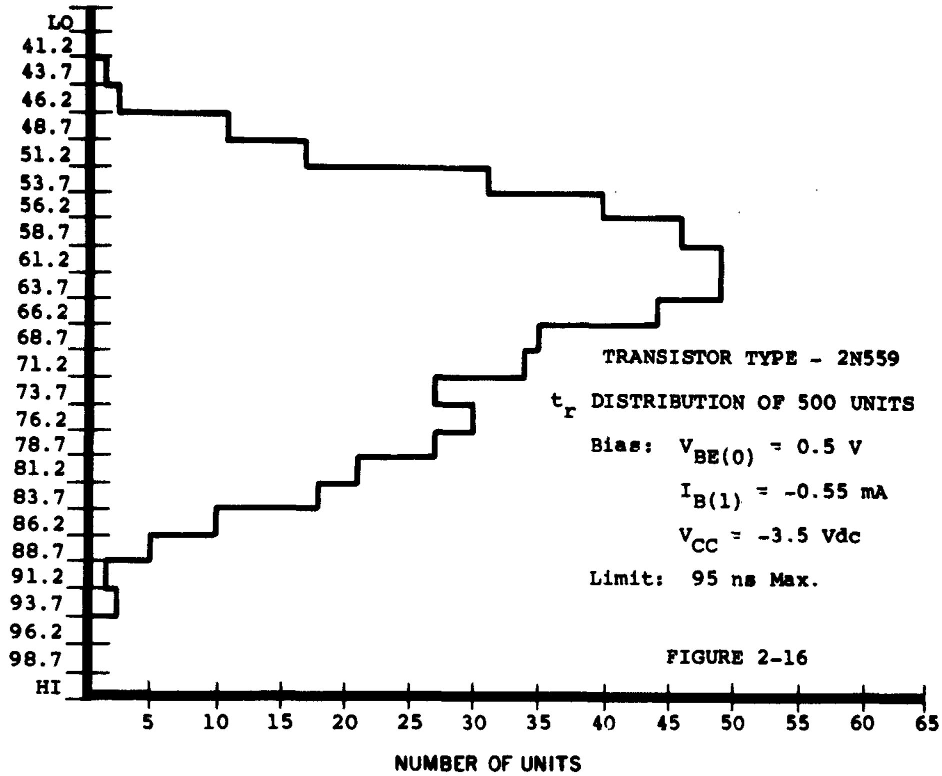


FIGURE 2-16

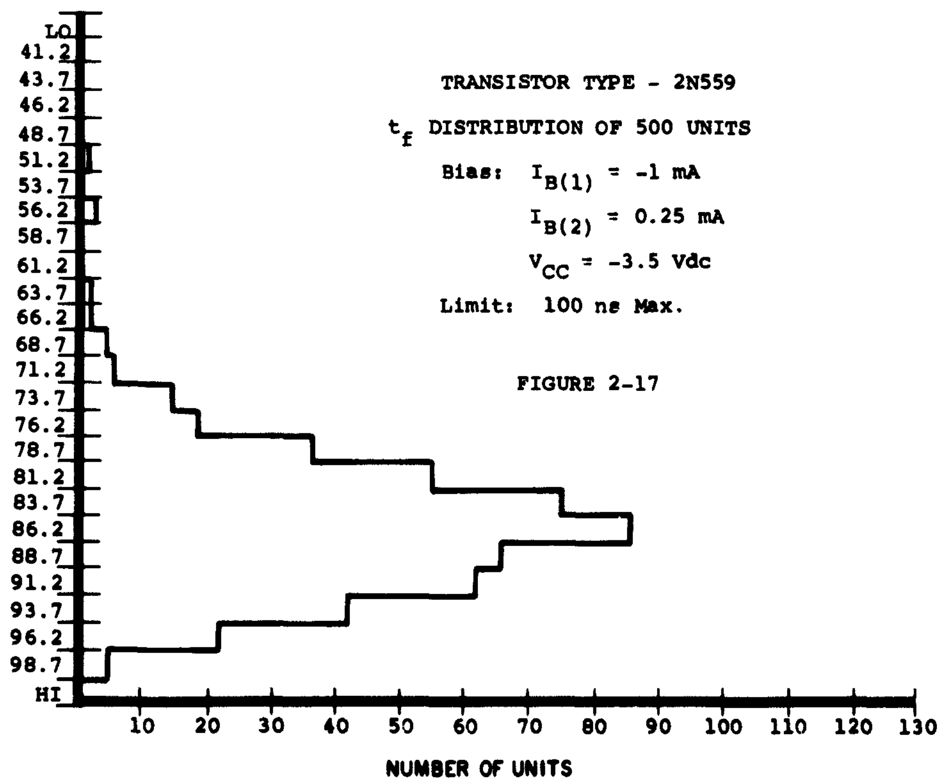
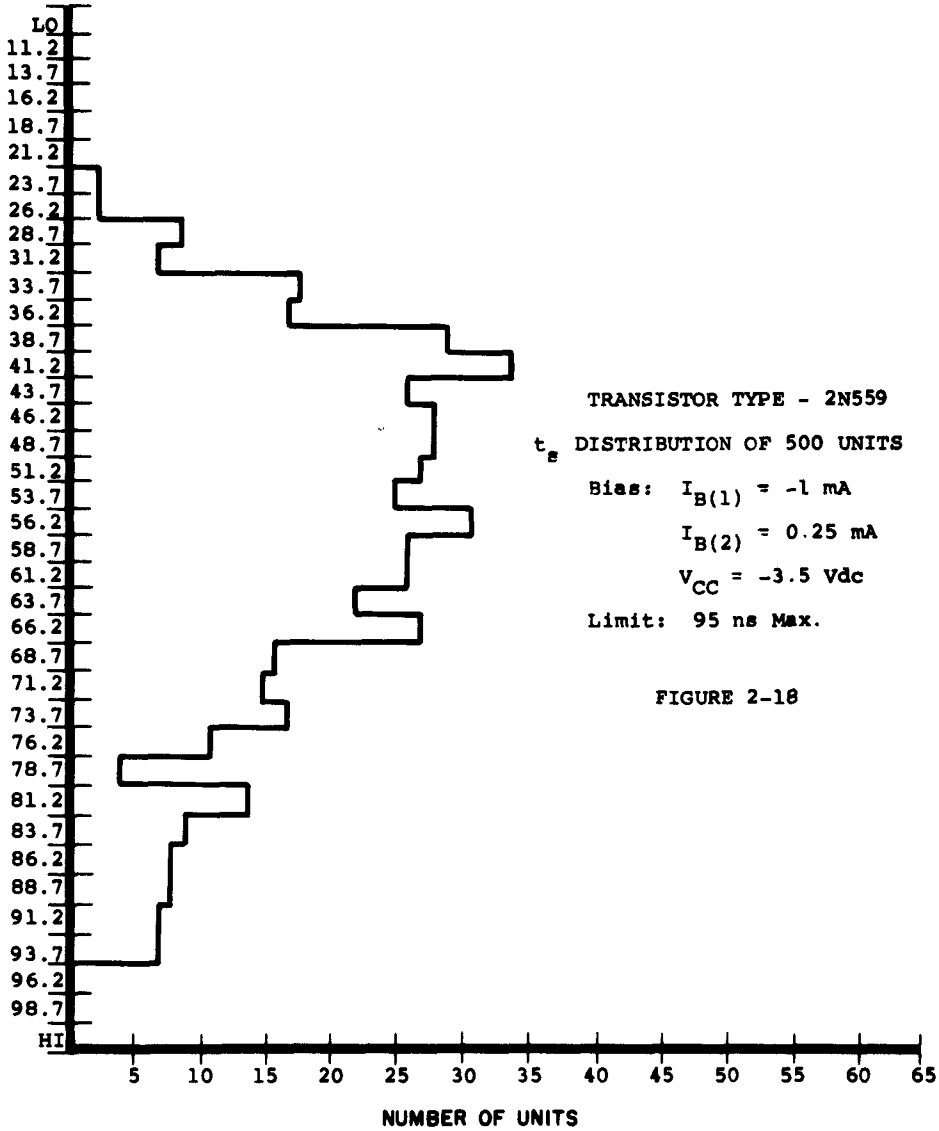


FIGURE 2-17



TRANSISTOR TYPE - 2N559

t_s DISTRIBUTION OF 500 UNITS

Bias: $I_{B(1)}$ = -1 mA

$I_{B(2)}$ = 0.25 mA

V_{CC} = -3.5 Vdc

Limit: 95 ns Max.

FIGURE 2-18

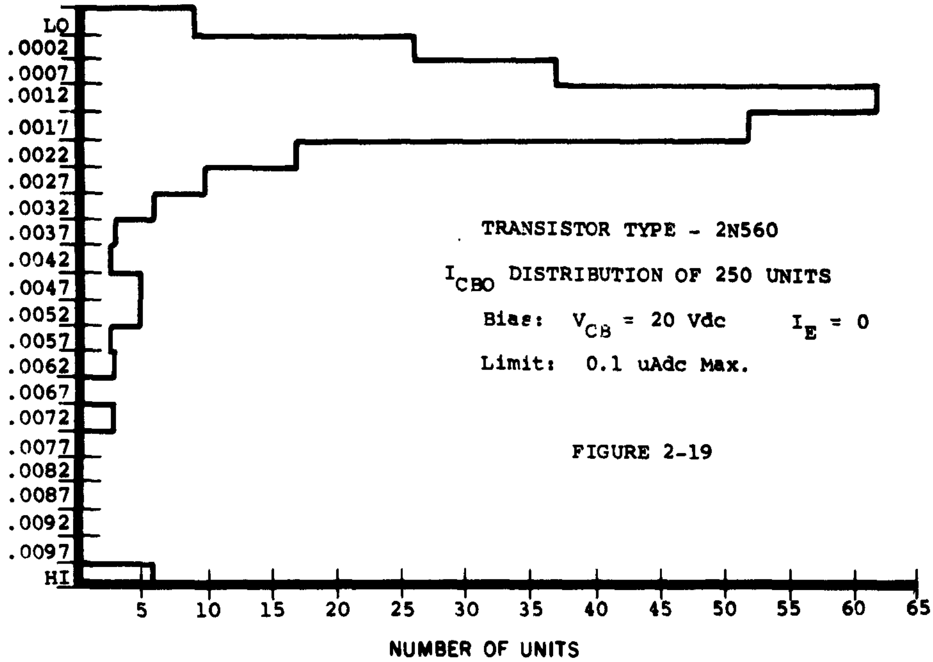


FIGURE 2-19

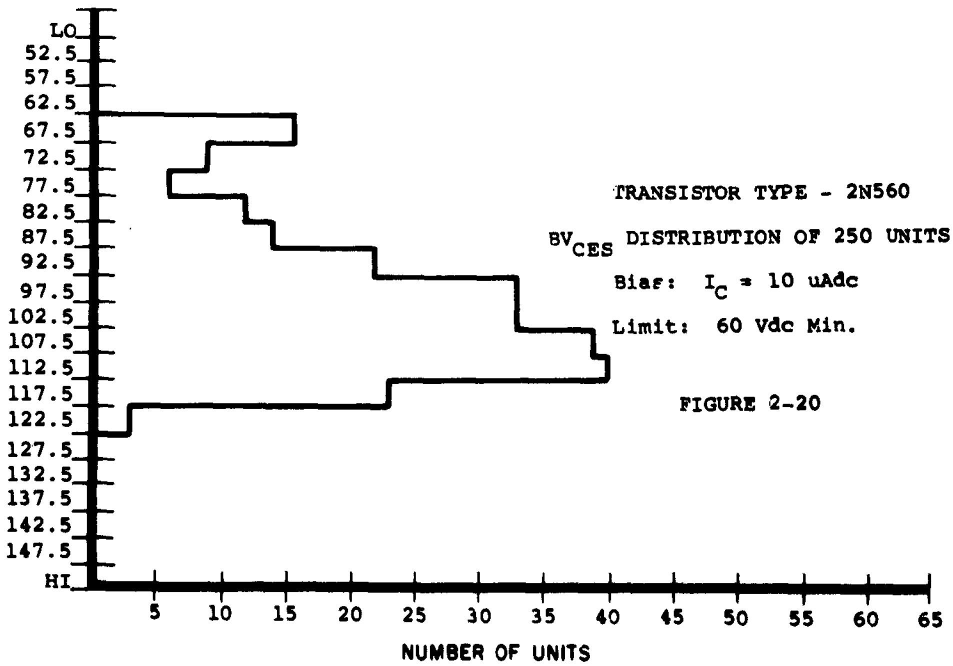


FIGURE 2-20

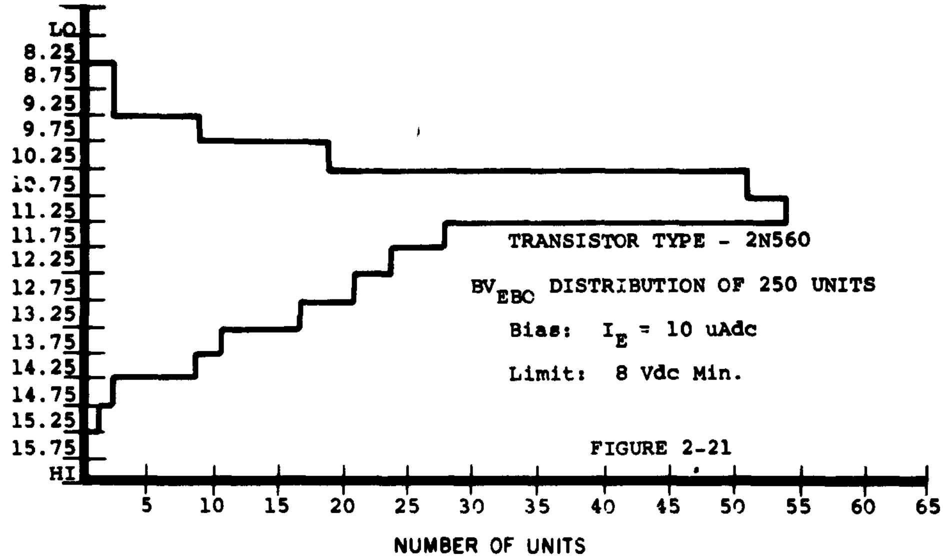


FIGURE 2-21

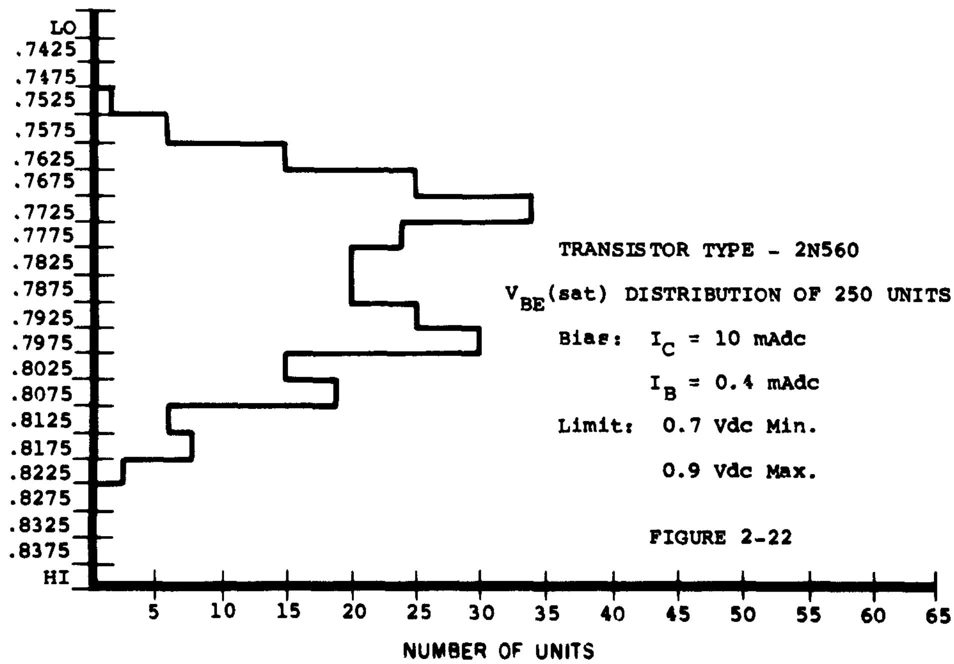
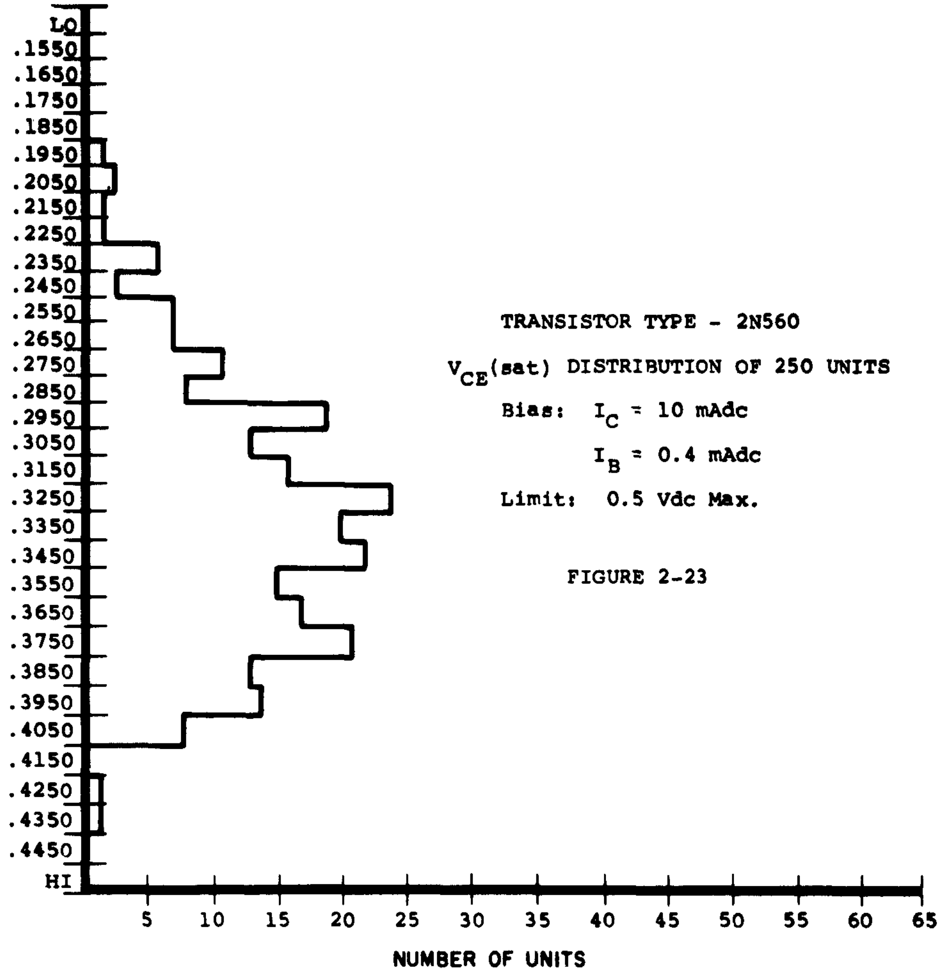


FIGURE 2-22



TRANSISTOR TYPE - 2N560

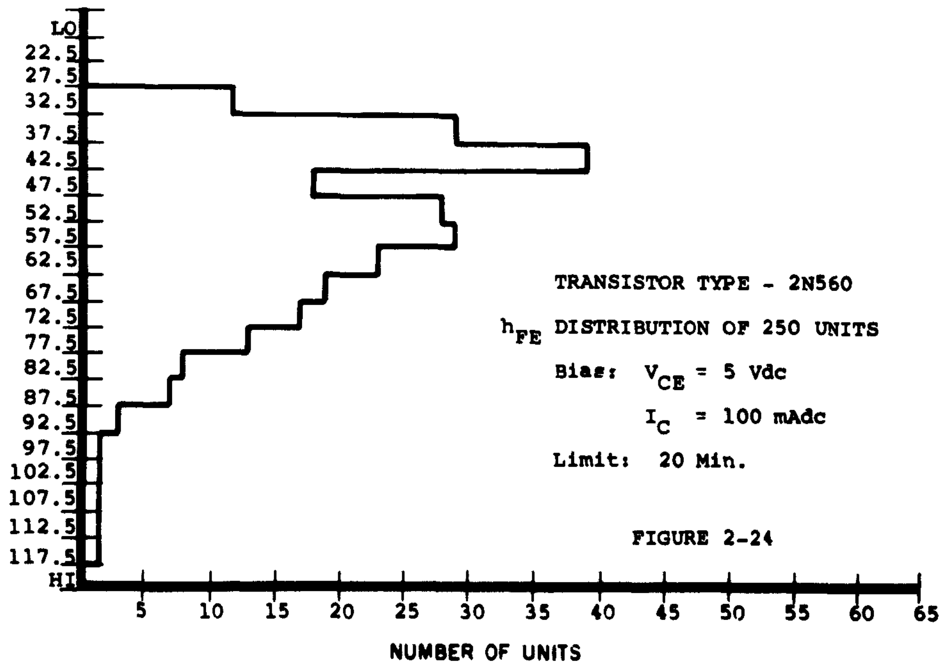
V_{CE}(sat) DISTRIBUTION OF 250 UNITS

Bias: I_C = 10 mAdc

I_B = 0.4 mAdc

Limit: 0.5 Vdc Max.

FIGURE 2-23



TRANSISTOR TYPE - 2N560

h_{FE} DISTRIBUTION OF 250 UNITS

Bias: V_{CE} = 5 Vdc

I_C = 100 mAdc

Limit: 20 Min.

FIGURE 2-24

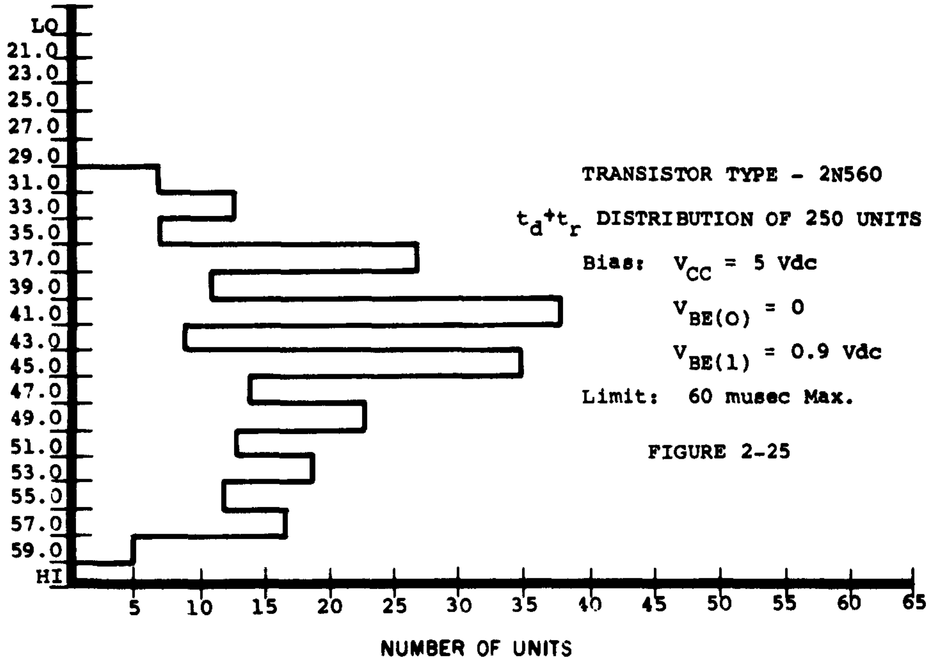


FIGURE 2-25

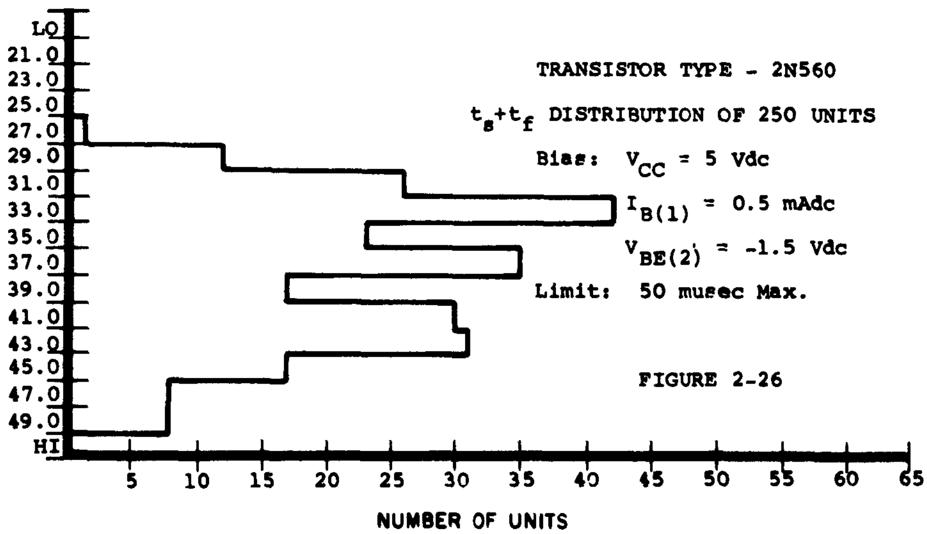
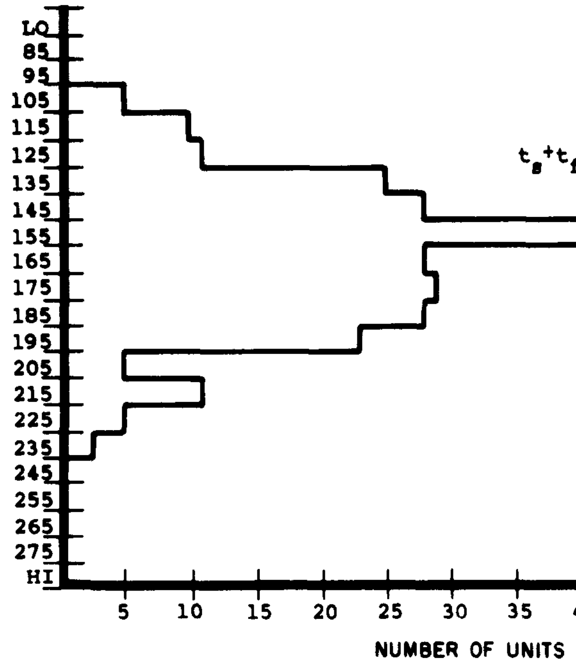


FIGURE 2-26



TRANSISTOR TYPE - 2N560

$t_s + t_f$ DISTRIBUTION OF 250 UNITS

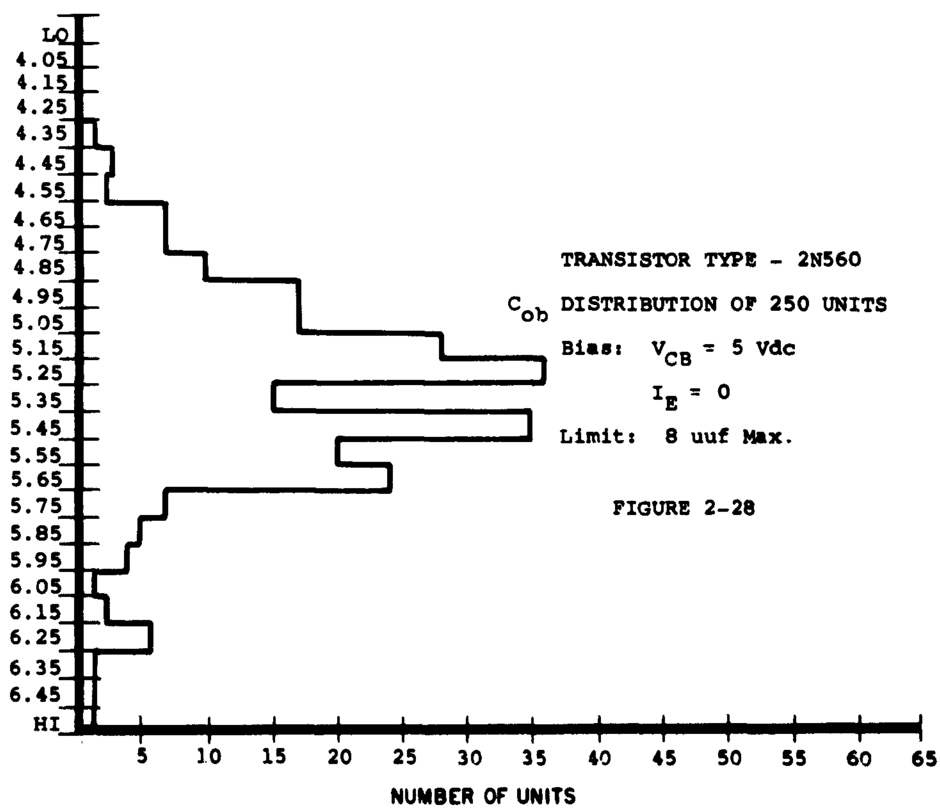
Bias: V_{CC} = 5 Vdc

$I_{B(1)}$ = 0.5 mAdc

$I_{B(2)}$ = 0.5 mAdc

Limit: 250 musec Max.

FIGURE 2-27



TRANSISTOR TYPE - 2N560

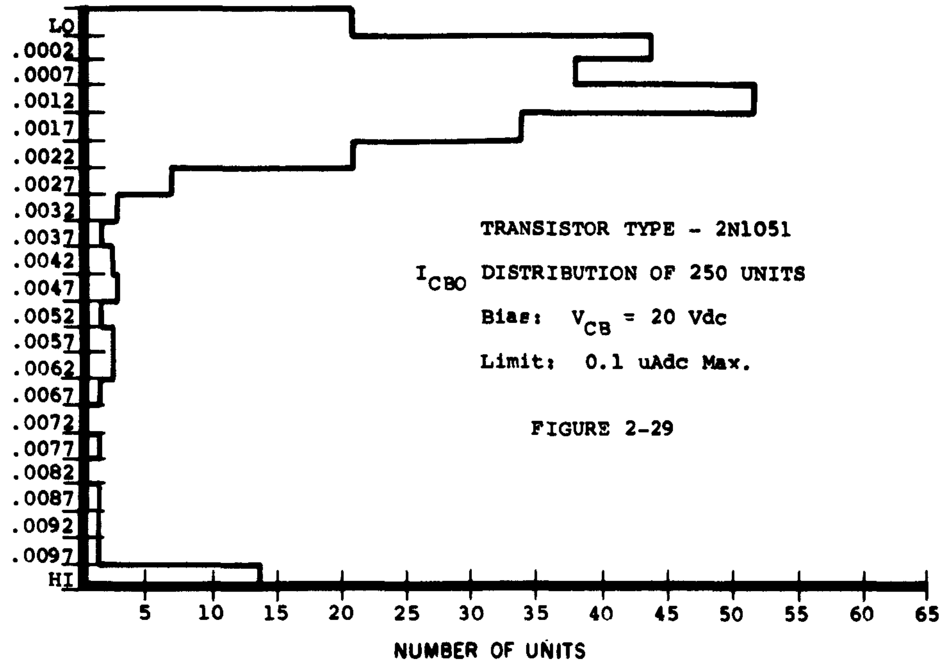
C_{ob} DISTRIBUTION OF 250 UNITS

Bias: V_{CB} = 5 Vdc

I_E = 0

Limit: 8 uuf Max.

FIGURE 2-28



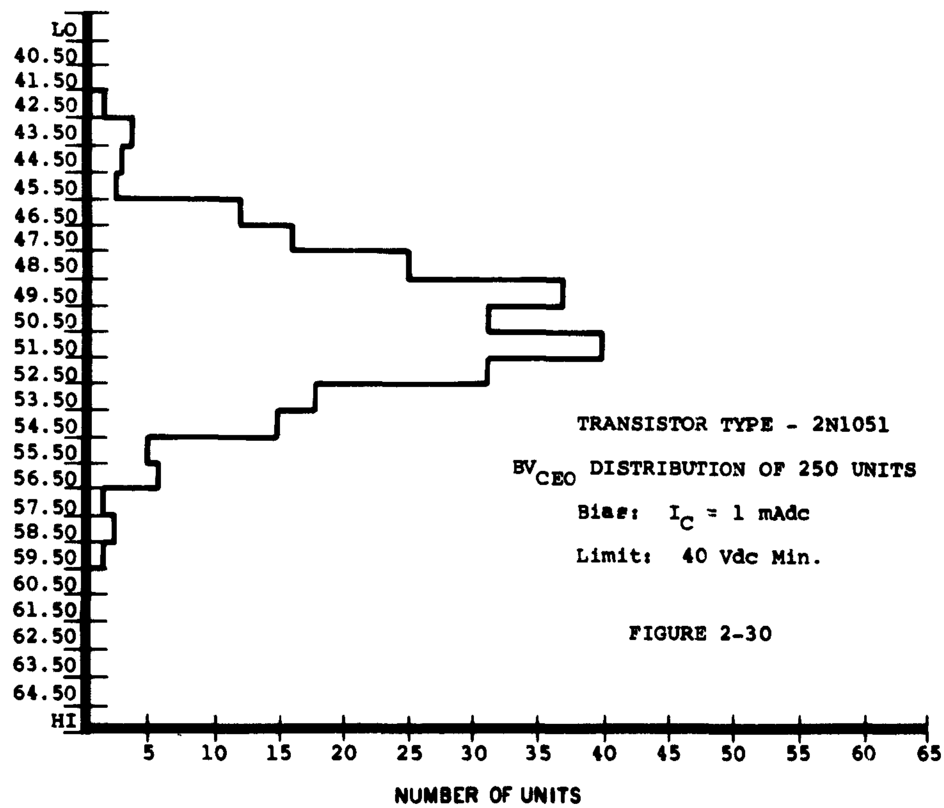
TRANSISTOR TYPE - 2N1051

I_{CBO} DISTRIBUTION OF 250 UNITS

Bias: V_{CB} = 20 Vdc

Limit: 0.1 uAdc Max.

FIGURE 2-29



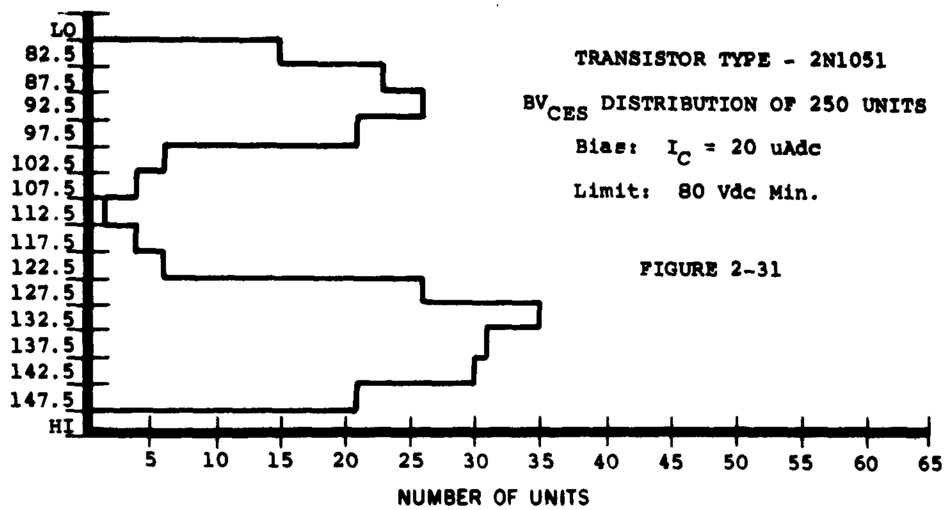
TRANSISTOR TYPE - 2N1051

BV_{CEO} DISTRIBUTION OF 250 UNITS

Bias: I_C = 1 mAdc

Limit: 40 Vdc Min.

FIGURE 2-30



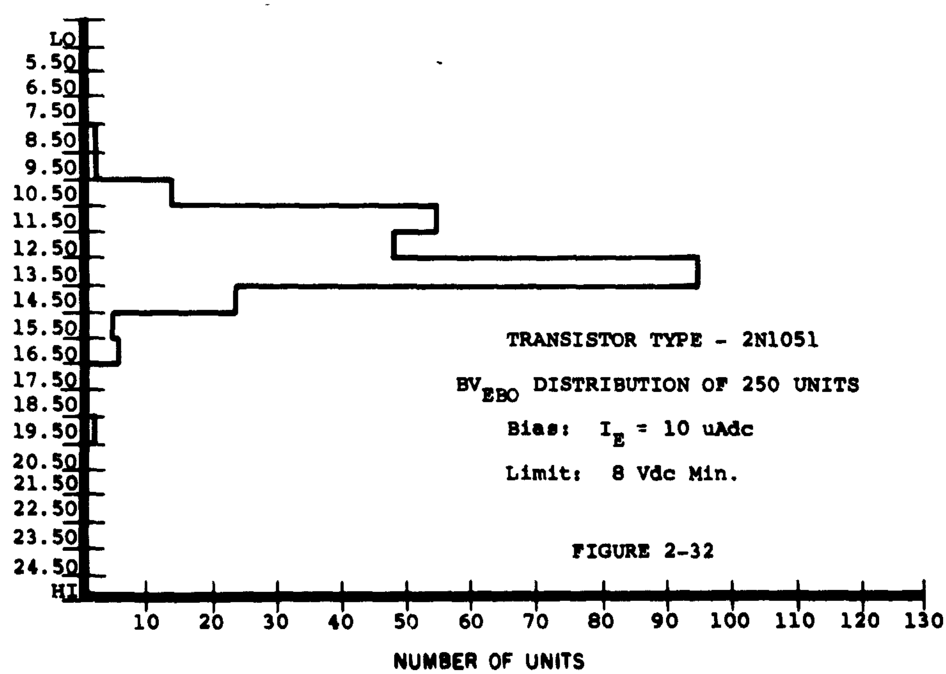
TRANSISTOR TYPE - 2N1051

BV_{CES} DISTRIBUTION OF 250 UNITS

Bias: I_C = 20 uAdc

Limit: 80 Vdc Min.

FIGURE 2-31



TRANSISTOR TYPE - 2N1051

BV_{EBO} DISTRIBUTION OF 250 UNITS

Bias: I_E = 10 uAdc

Limit: 8 Vdc Min.

FIGURE 2-32

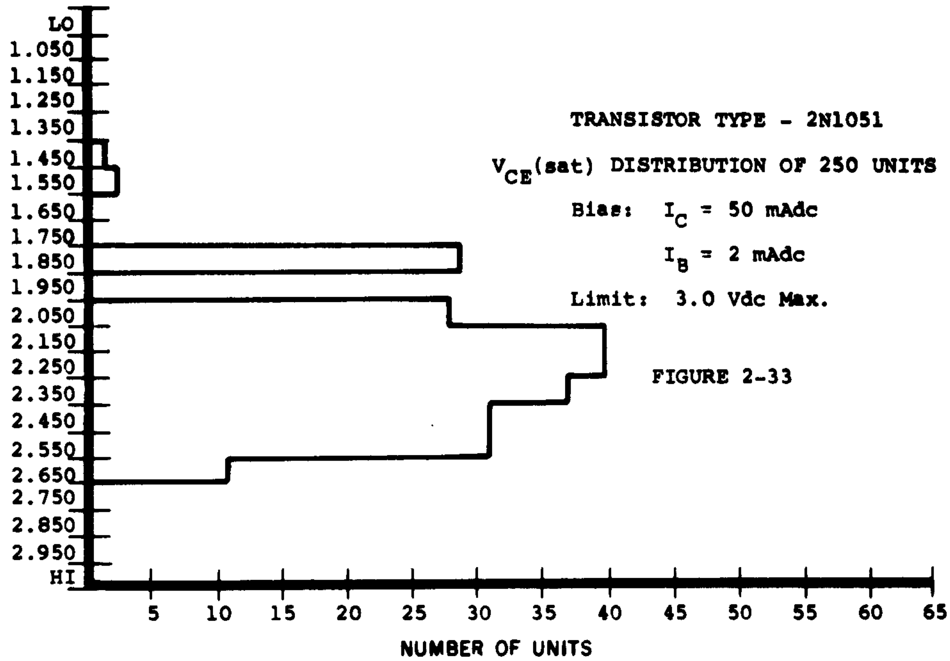


FIGURE 2-33

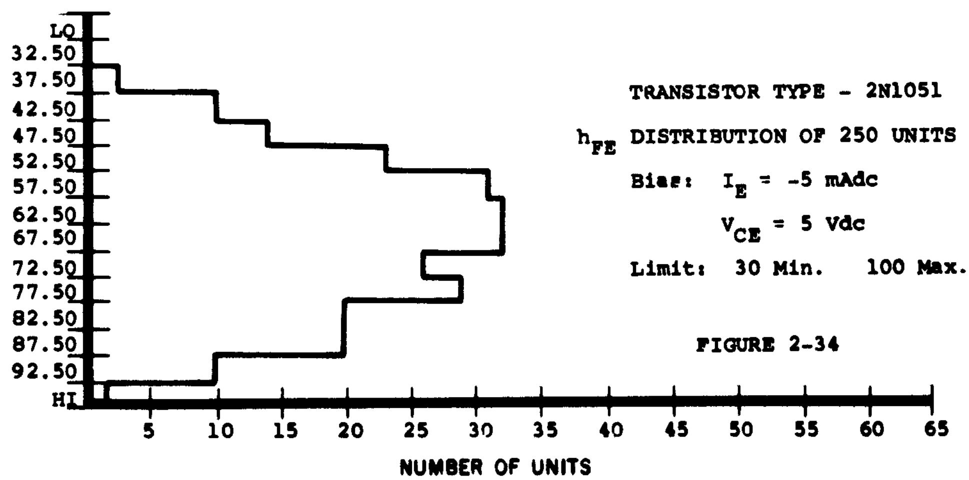


FIGURE 2-34

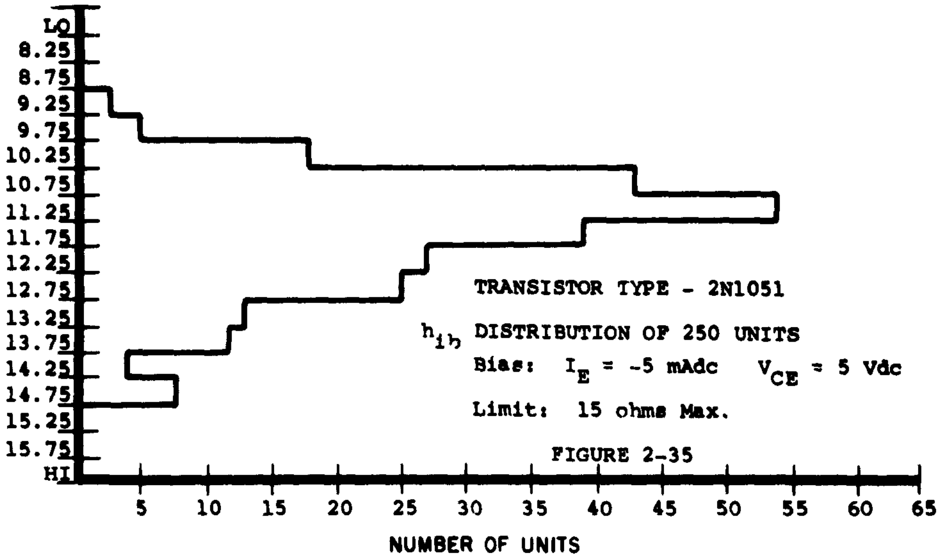


FIGURE 2-35

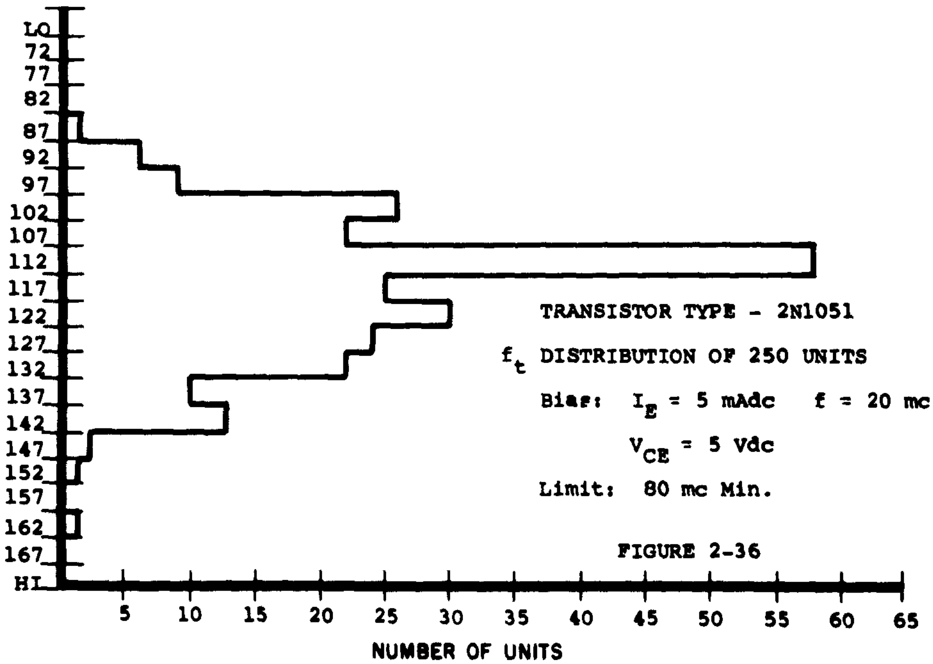


FIGURE 2-36

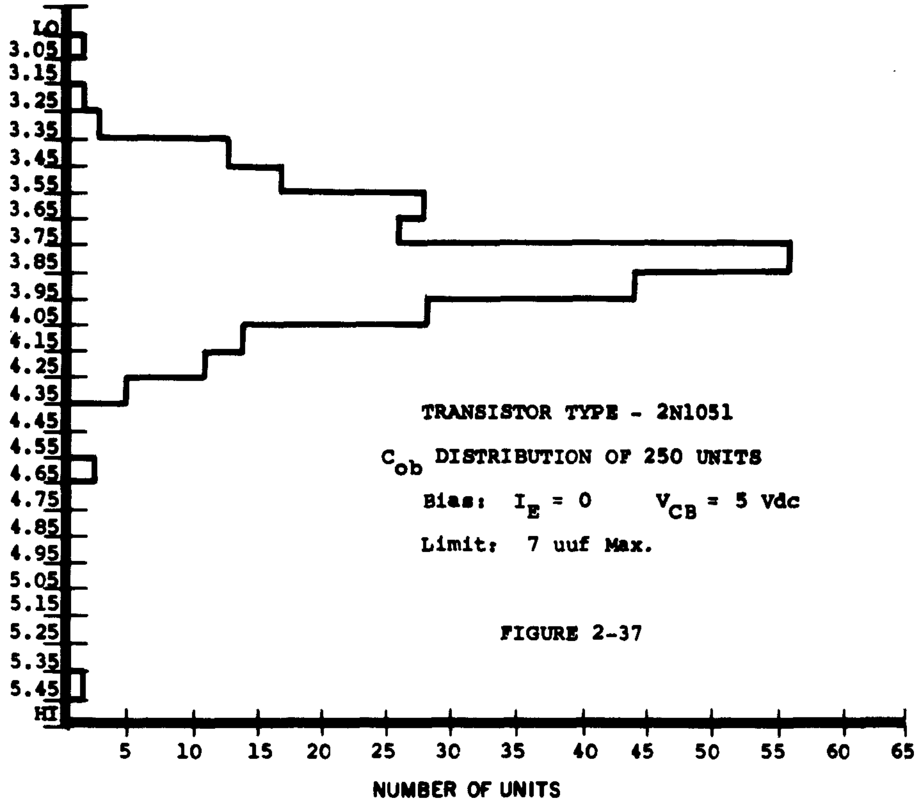


FIGURE 2-37

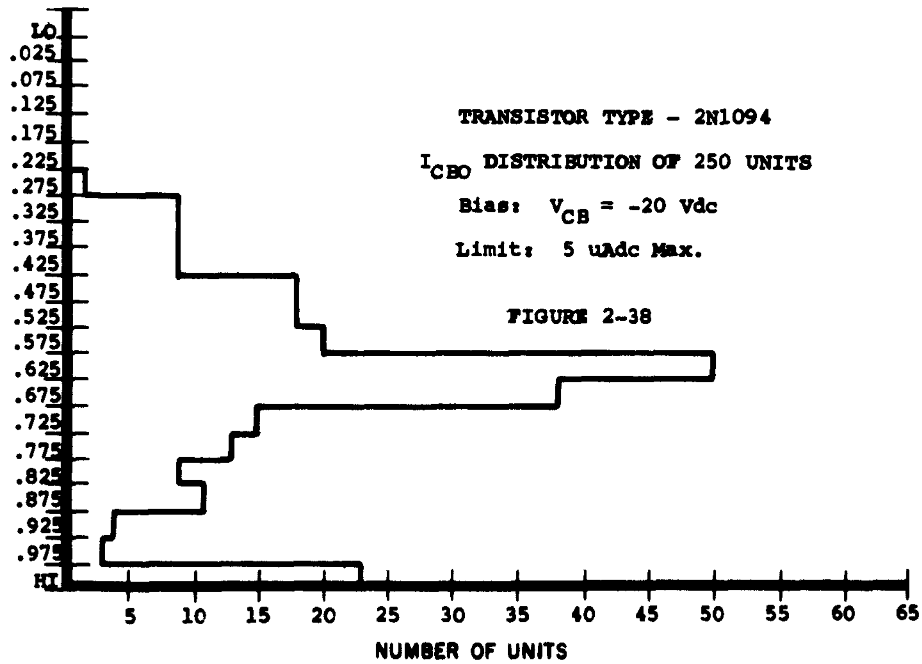
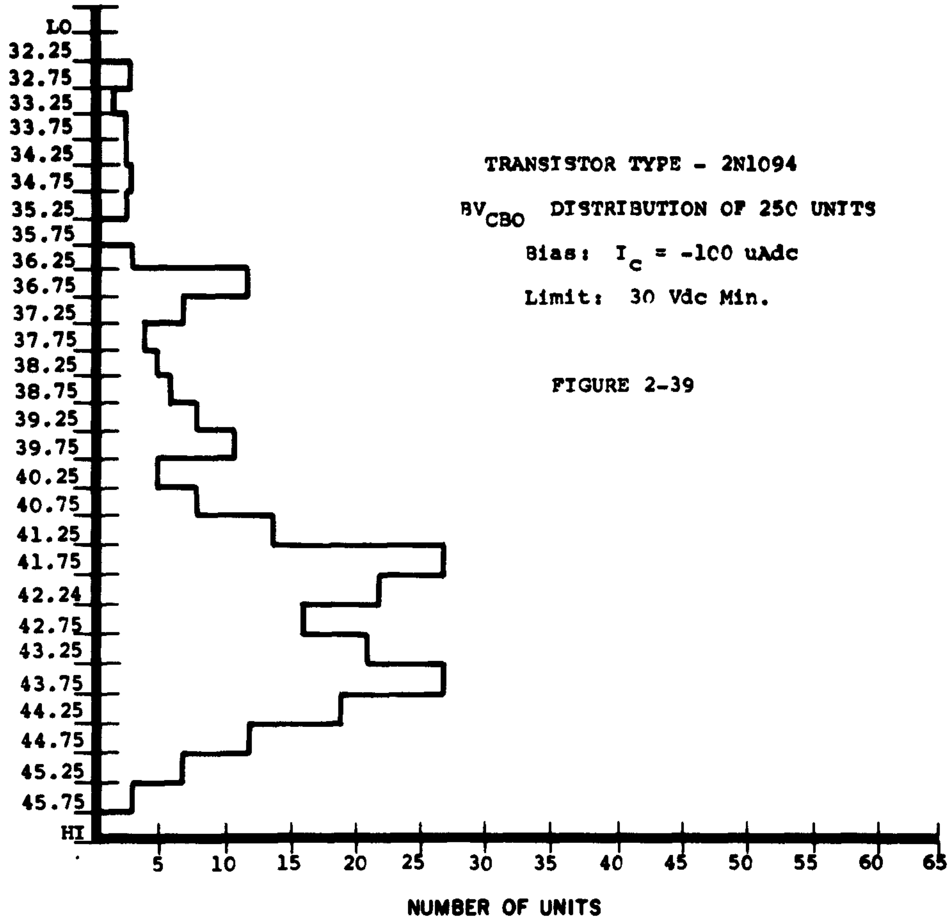


FIGURE 2-38



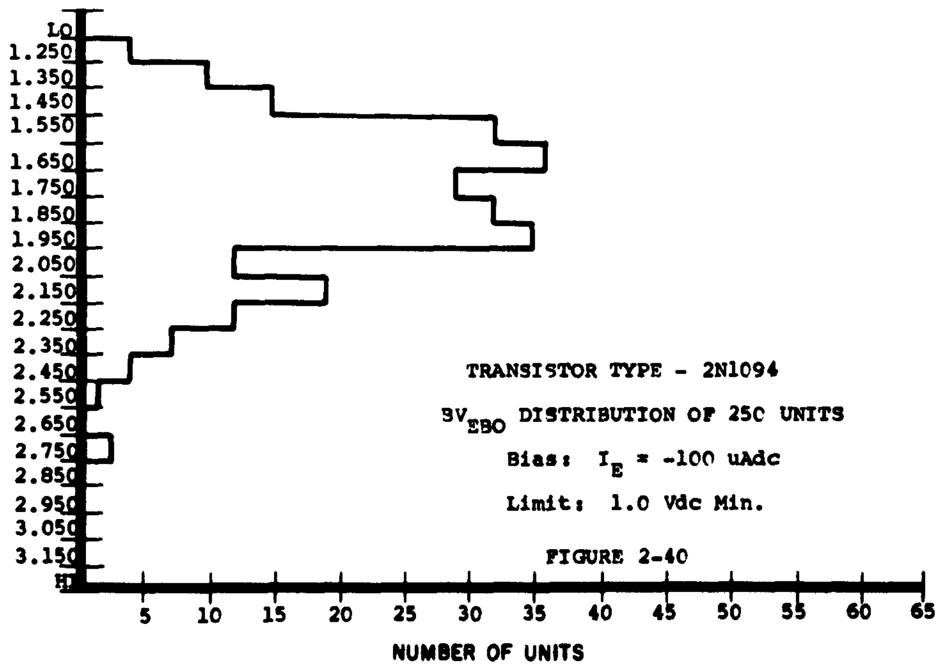
TRANSISTOR TYPE - 2N1094

BV_{CBO} DISTRIBUTION OF 250 UNITS

Bias: I_C = -100 uAdc

Limit: 30 Vdc Min.

FIGURE 2-39



TRANSISTOR TYPE - 2N1094

BV_{EBO} DISTRIBUTION OF 250 UNITS

Bias: I_E = -100 uAdc

Limit: 1.0 Vdc Min.

FIGURE 2-40

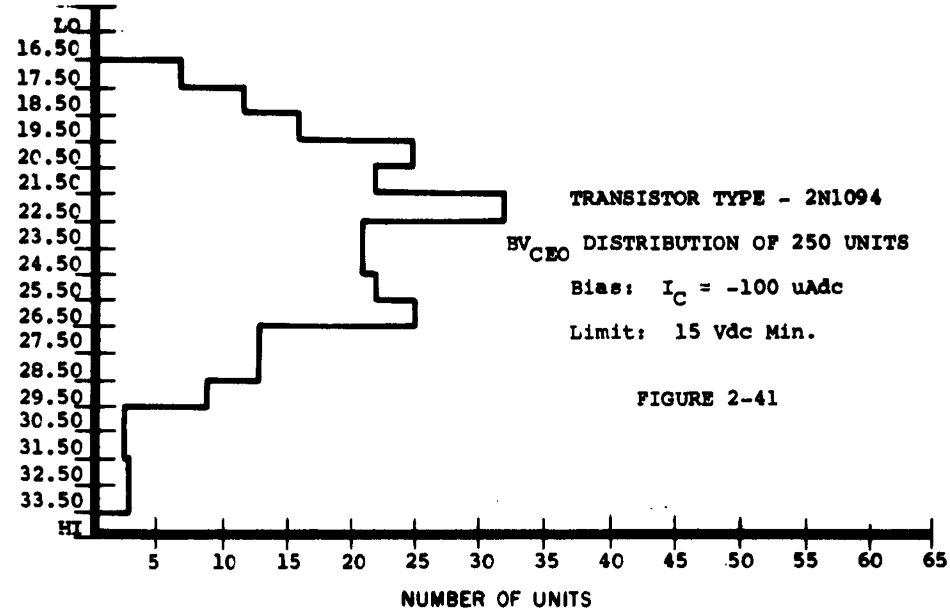


FIGURE 2-41

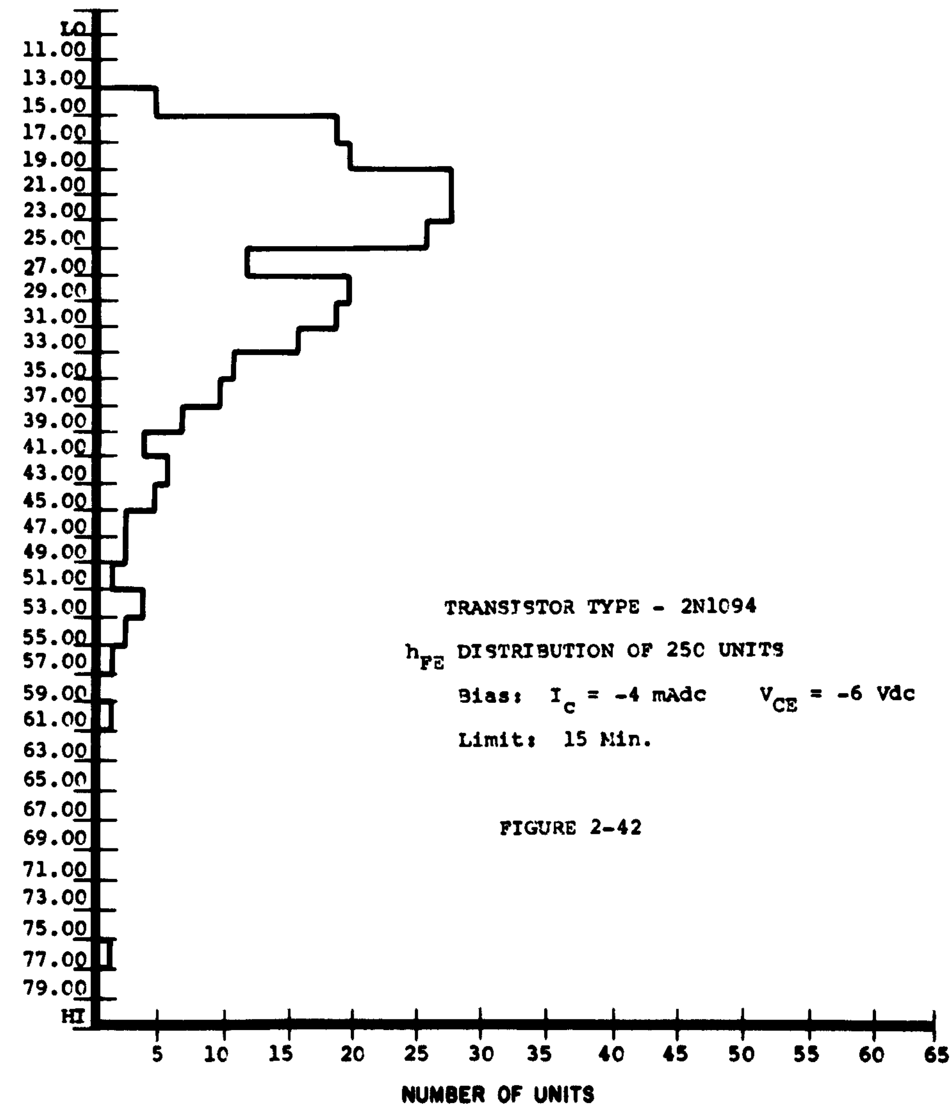
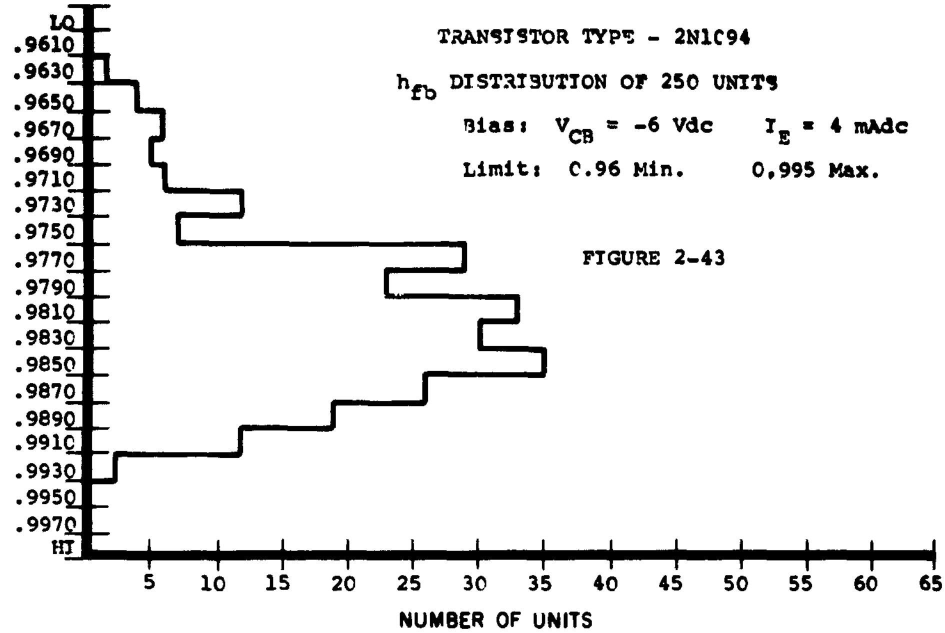


FIGURE 2-42



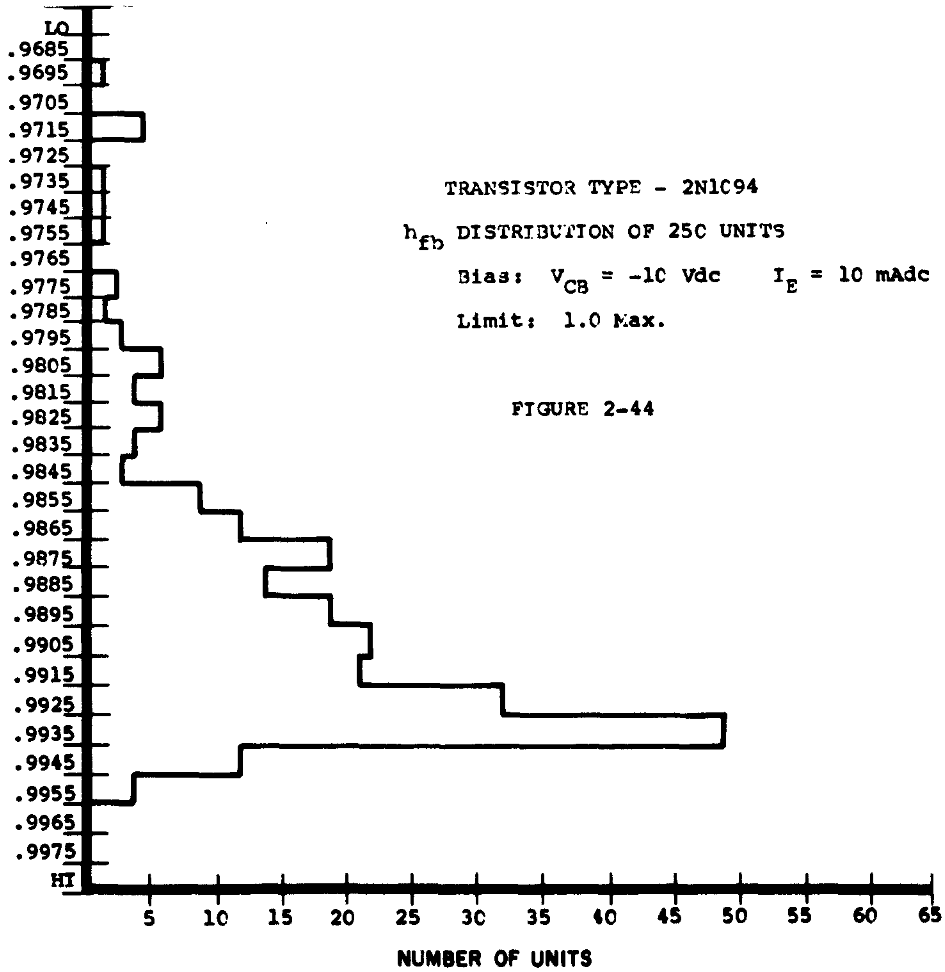
TRANSISTOR TYPE – 2N1C94

h_{fb} DISTRIBUTION OF 250 UNITS

Bias: V_{CB} = -6 Vdc I_E = 4 mAdc

Limit: 0.96 Min. 0.995 Max.

FIGURE 2-43



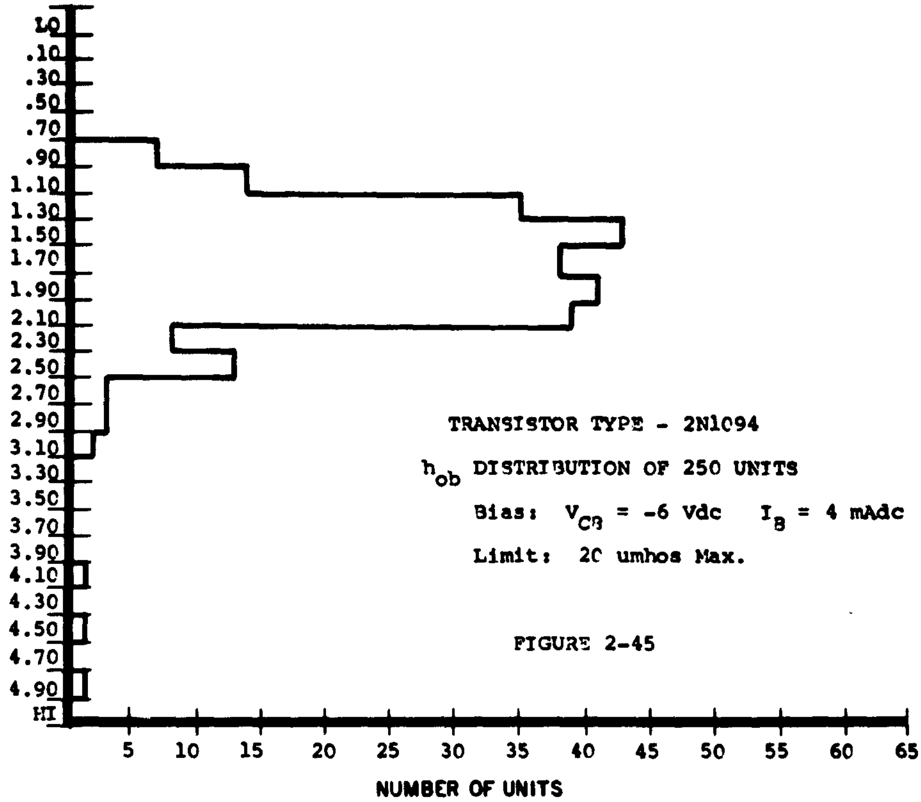
TRANSISTOR TYPE – 2N1C94

h_{fb} DISTRIBUTION OF 25C UNITS

Bias: V_{CB} = -1C Vdc I_E = 10 mAdc

Limit: 1.0 Max.

FIGURE 2-44



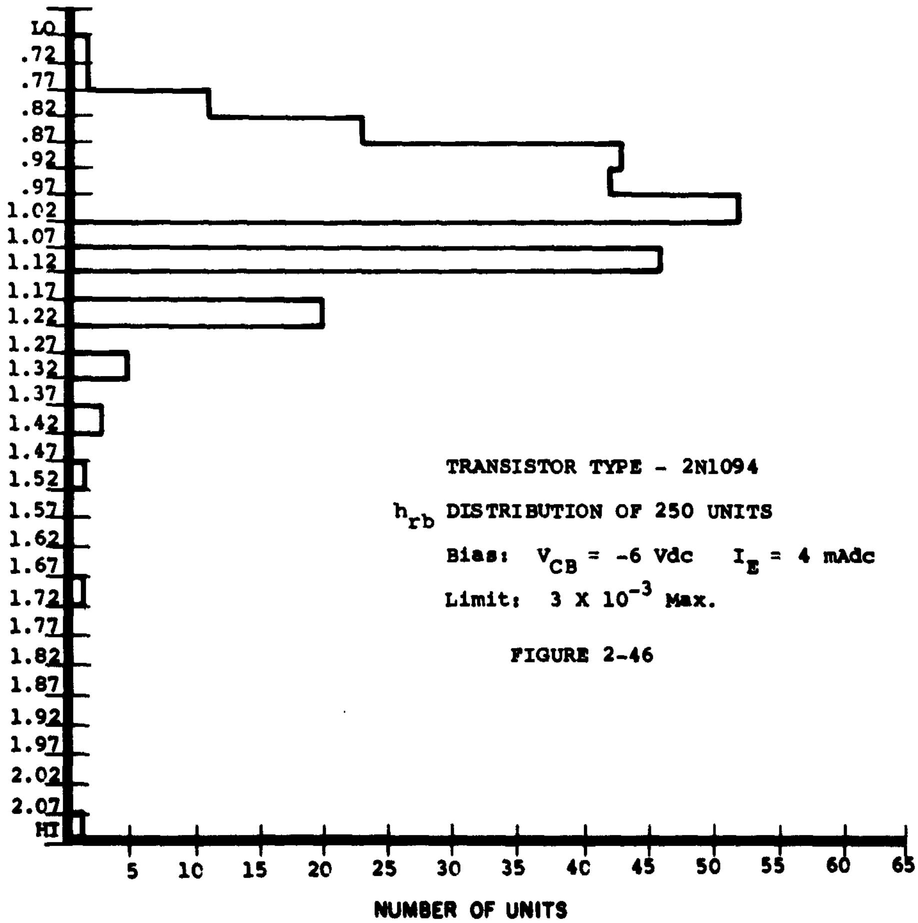
TRANSISTOR TYPE - 2N1094

h_{ob} DISTRIBUTION OF 250 UNITS

Bias: V_{CB} = -6 Vdc I_B = 4 mAdc

Limit: 20 umhos Max.

FIGURE 2-45



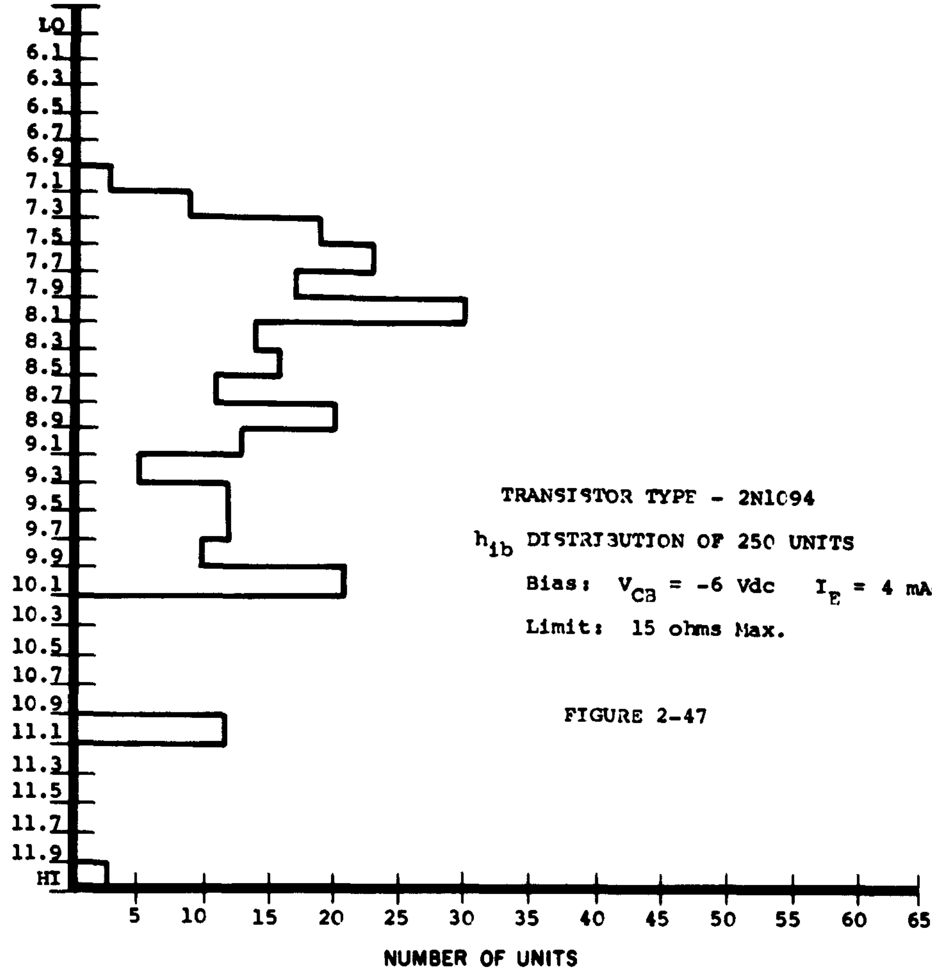
TRANSISTOR TYPE - 2N1094

h_{rb} DISTRIBUTION OF 250 UNITS

Bias: V_{CB} = -6 Vdc I_E = 4 mAdc

Limit: 3×10^{-3} Max.

FIGURE 2-46



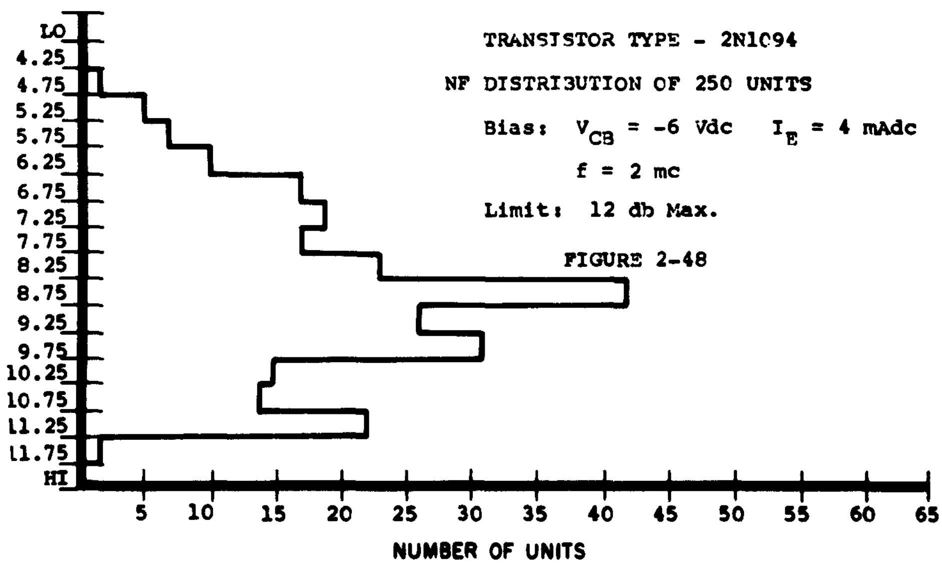
TRANSISTOR TYPE - 2N1094

h_{ib} DISTRIBUTION OF 250 UNITS

Bias: V_{CB} = -6 Vdc I_E = 4 mAdc

Limit: 15 ohms Max.

FIGURE 2-47



TRANSISTOR TYPE - 2N1094

NF DISTRIBUTION OF 250 UNITS

Bias: V_{CB} = -6 Vdc I_E = 4 mAdc

f = 2 mc

Limit: 12 db Max.

FIGURE 2-48

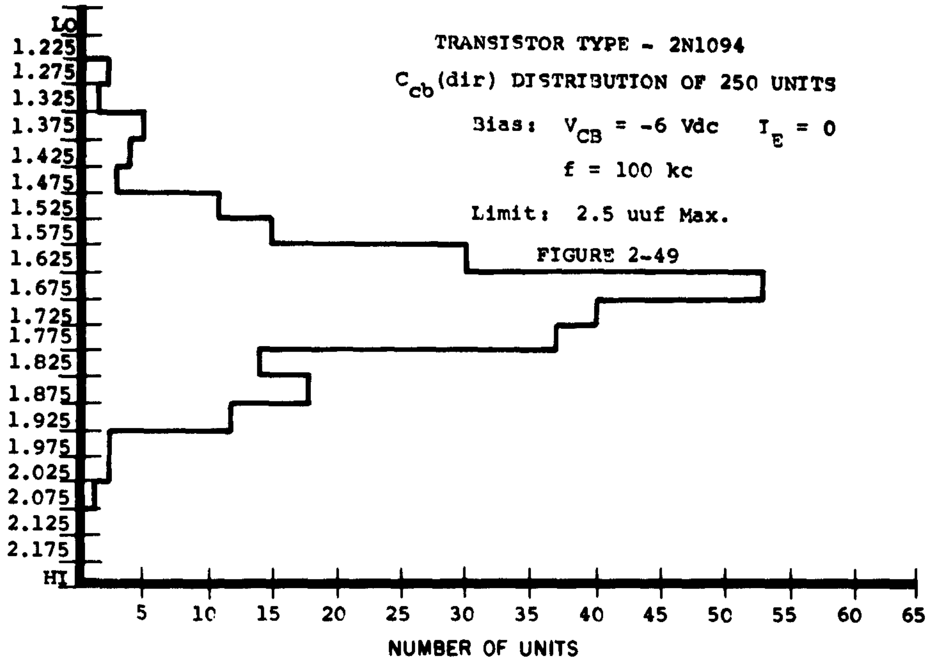


FIGURE 2-49

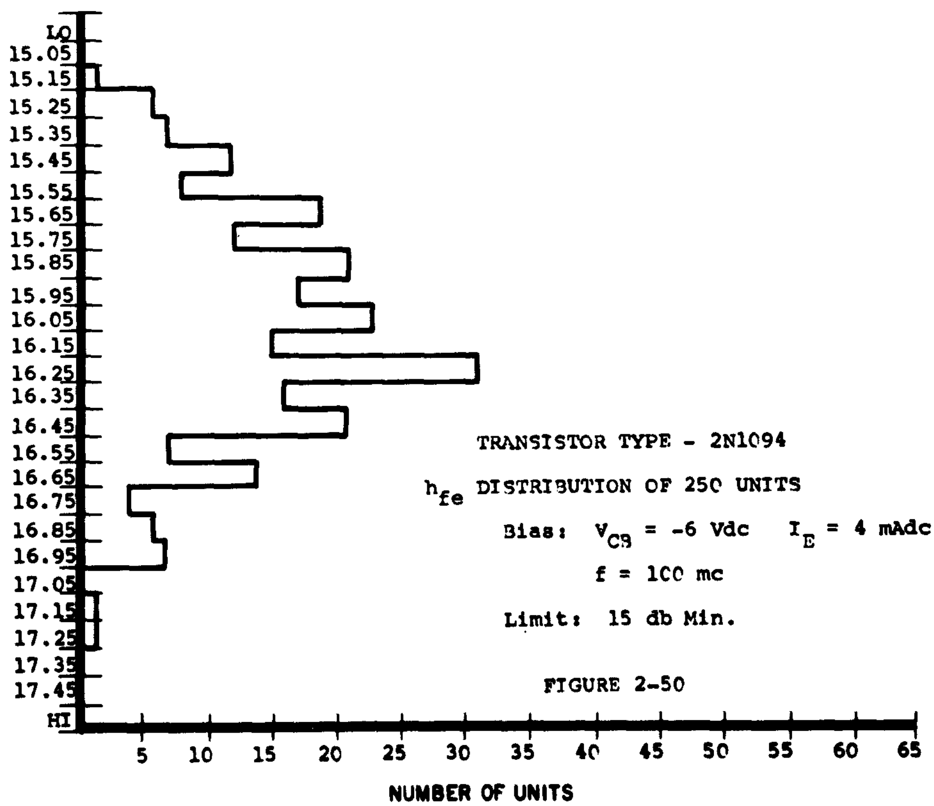
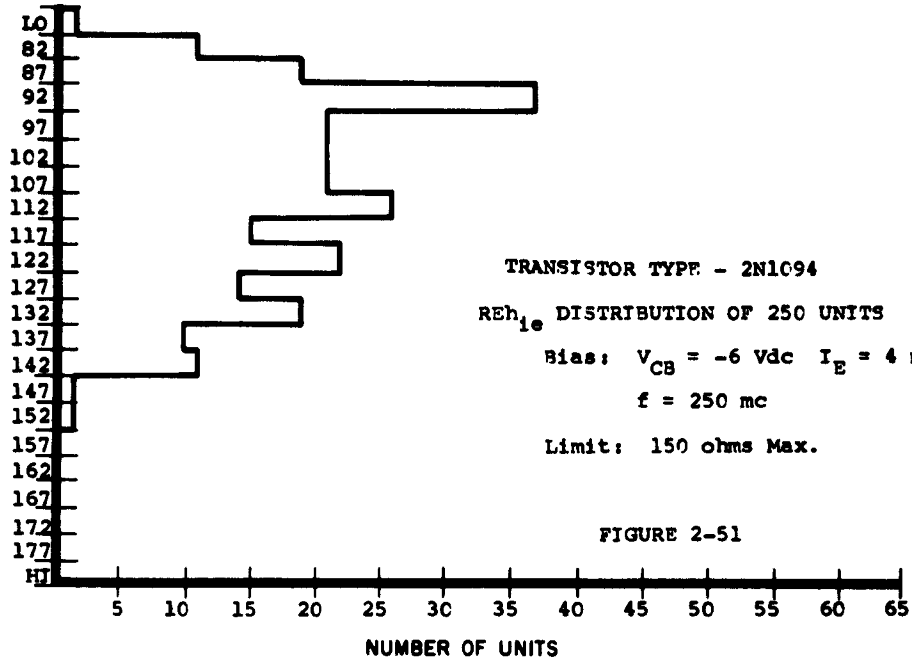


FIGURE 2-50



TRANSISTOR TYPE - 2N1094

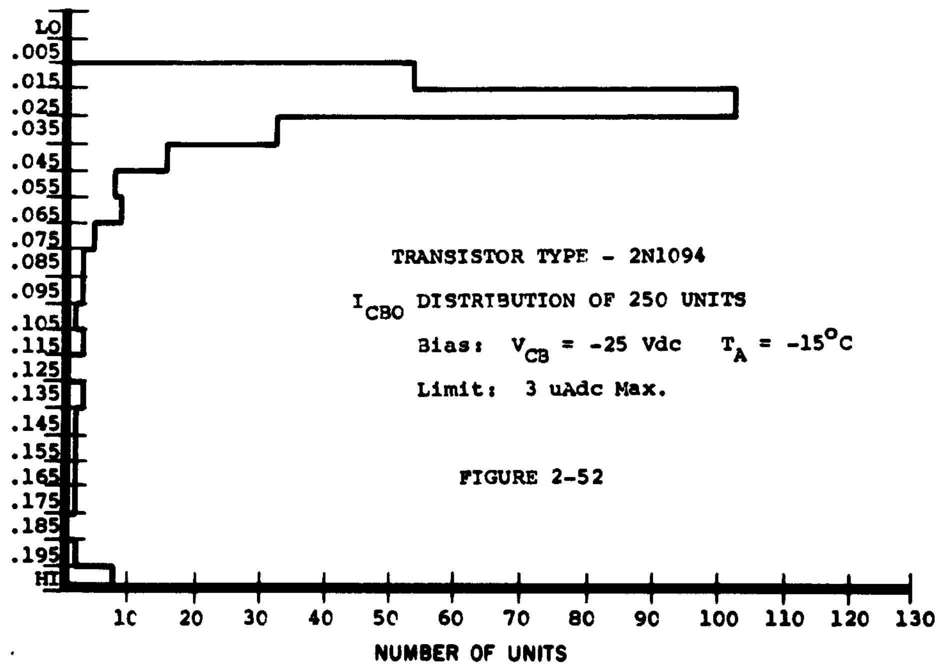
REh_{ie} DISTRIBUTION OF 250 UNITS

Bias: V_{CB} = -6 Vdc I_E = 4 mAdc

f = 250 mc

Limit: 150 ohms Max.

FIGURE 2-51



TRANSISTOR TYPE - 2N1094

I_{CBO} DISTRIBUTION OF 250 UNITS

Bias: V_{CB} = -25 Vdc T_A = -15°C

Limit: 3 uAdc Max.

FIGURE 2-52

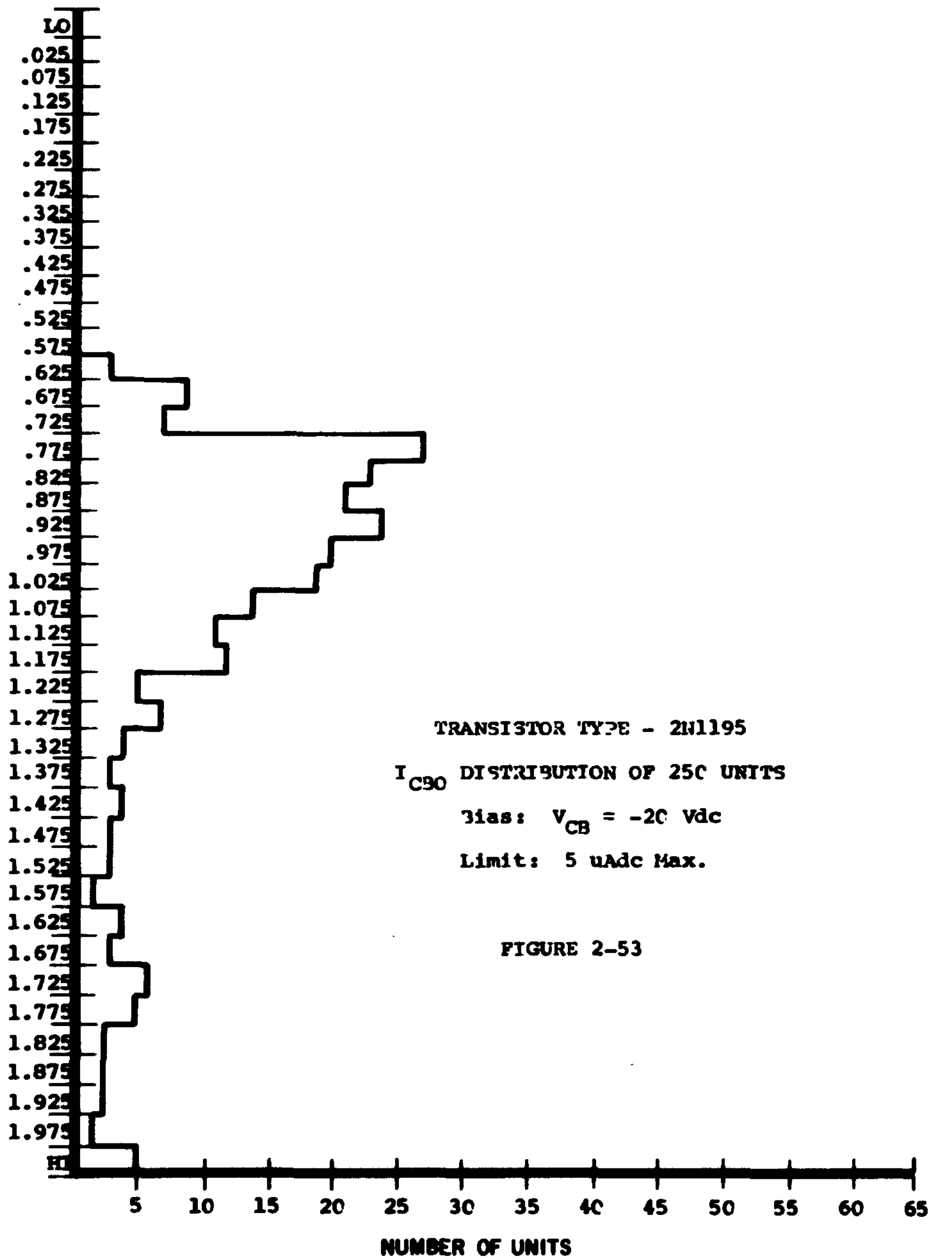
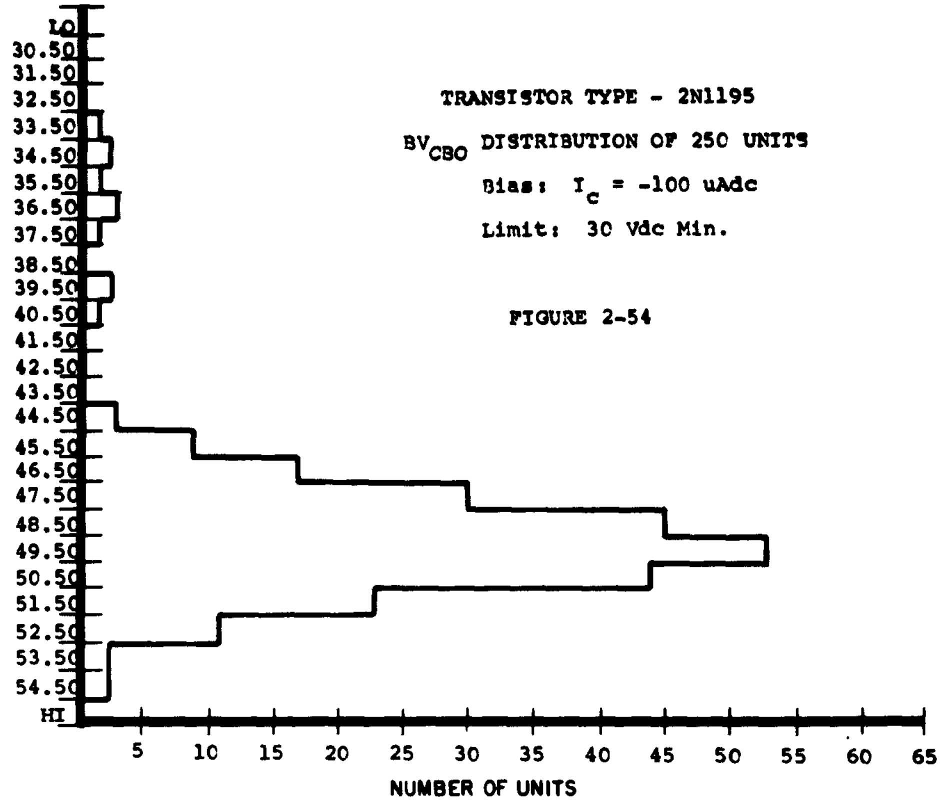

LO
.025
.075
.125
.175
.225
.275
.325
.375
.425
.475
.525
.575
.625
.675
.725
.775
.825
.875
.925
.975
1.025
1.075
1.125
1.175
1.225
1.275
1.325
1.375
1.425
1.475
1.525
1.575
1.625
1.675
1.725
1.775
1.825
1.875
1.925
1.975
HI
5 10 15 20 25 30 35 40 45 50 55 60 65
NUMBER OF UNITS
TRANSISTOR TYPE - 2N1195
I_{CBO} DISTRIBUTION OF 250 UNITS
Bias: V_{CB} = -20 Vdc
Limit: 5 uAdc Max.

FIGURE 2-53



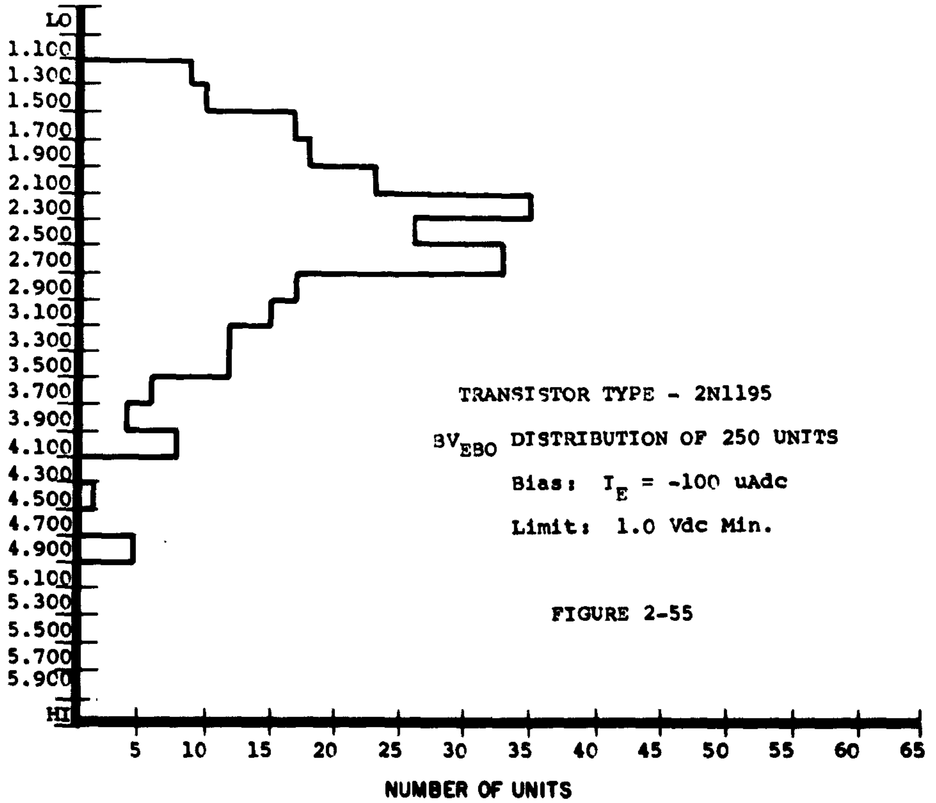
TRANSISTOR TYPE - 2N1195

BV_{CBO} DISTRIBUTION OF 250 UNITS

Bias: I_c = -100 uAdc

Limit: 30 Vdc Min.

FIGURE 2-54



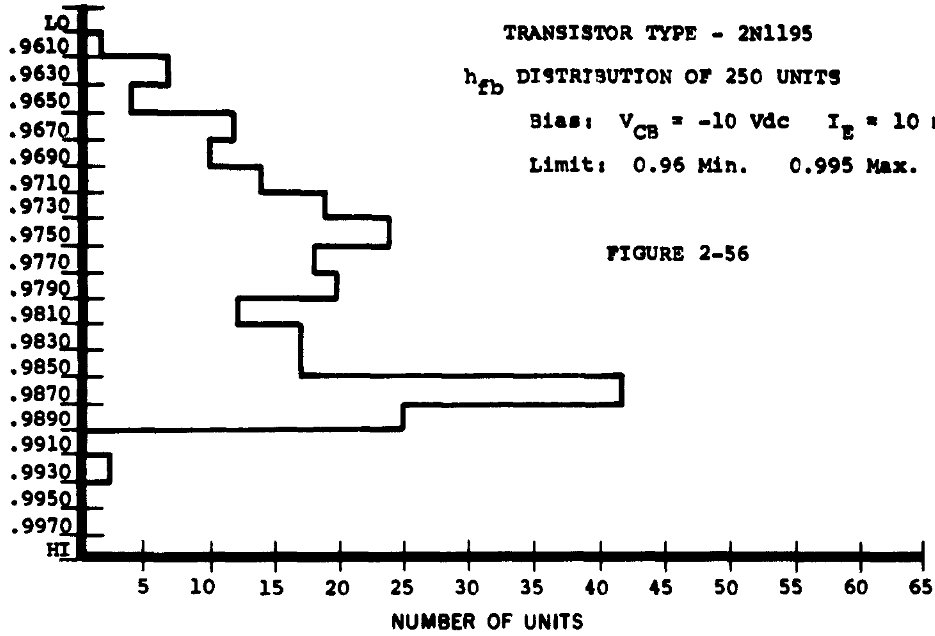
TRANSISTOR TYPE - 2N1195

BV_{EBO} DISTRIBUTION OF 250 UNITS

Bias: I_E = -100 uAdc

Limit: 1.0 Vdc Min.

FIGURE 2-55



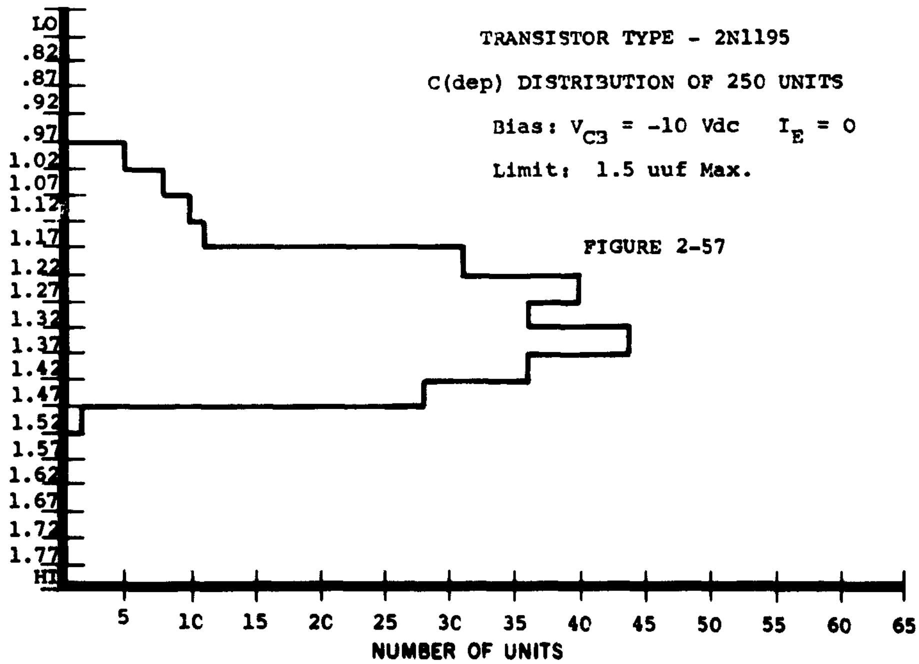
TRANSISTOR TYPE - 2N1195

h_{fb} DISTRIBUTION OF 250 UNITS

Bias: V_{CB} = -10 Vdc I_E = 10 mAdc

Limit: 0.96 Min. 0.995 Max.

FIGURE 2-56



TRANSISTOR TYPE - 2N1195

C(dep) DISTRIBUTION OF 250 UNITS

Bias: V_{CB} = -10 Vdc I_E = 0

Limit: 1.5 uuf Max.

FIGURE 2-57

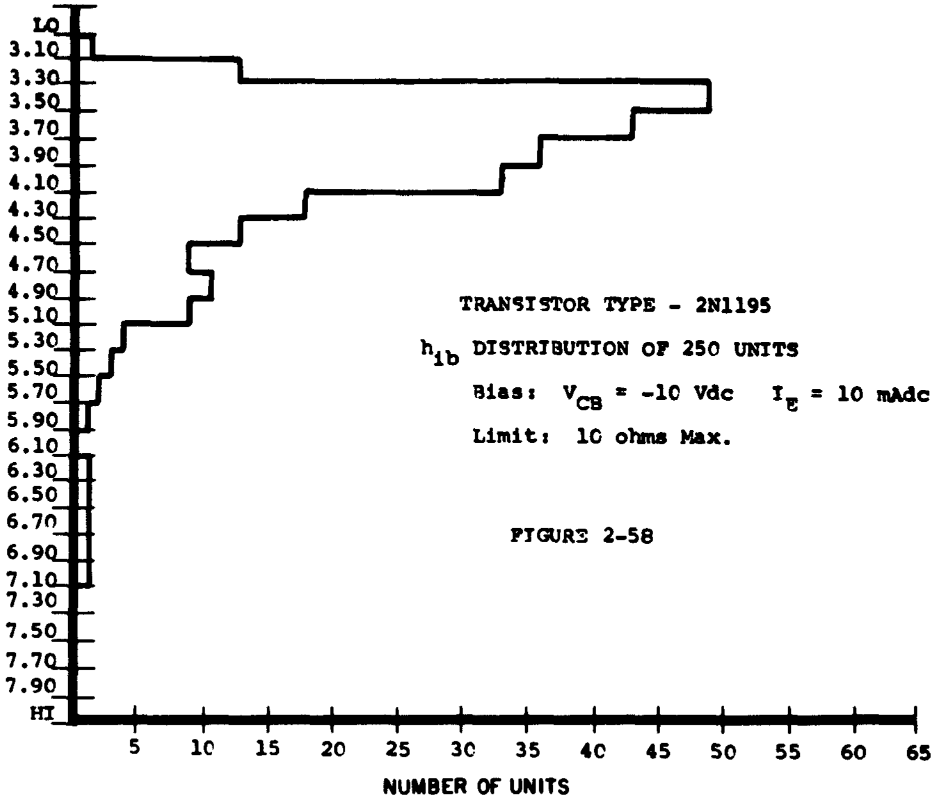


FIGURE 2-58

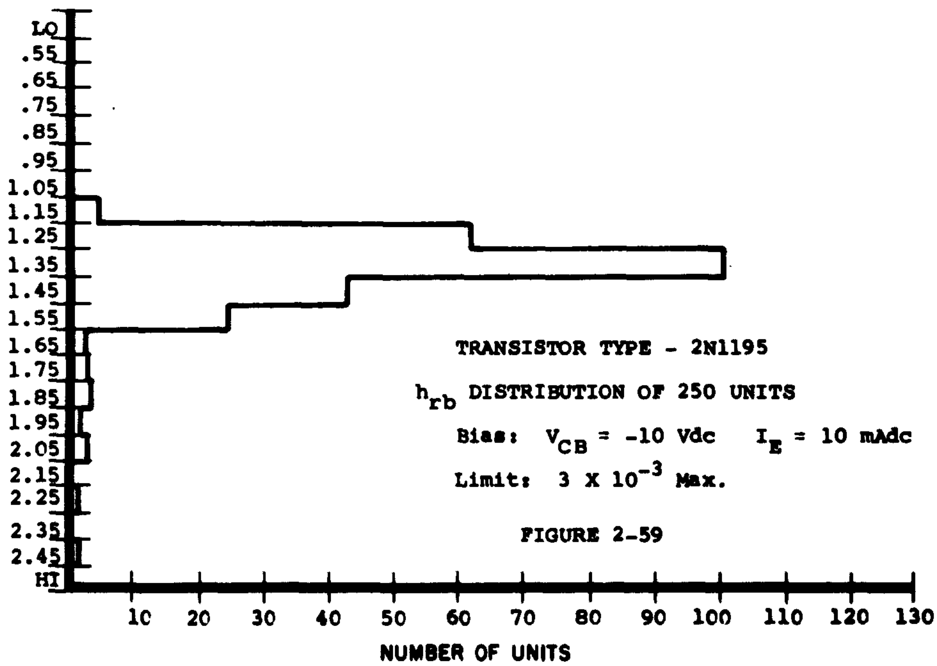


FIGURE 2-59

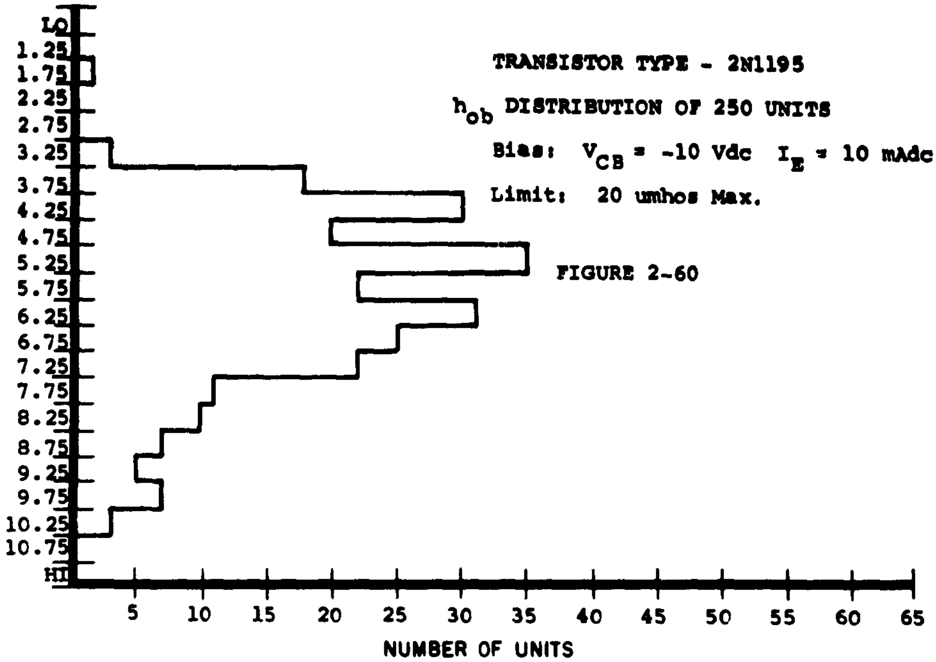


FIGURE 2-60

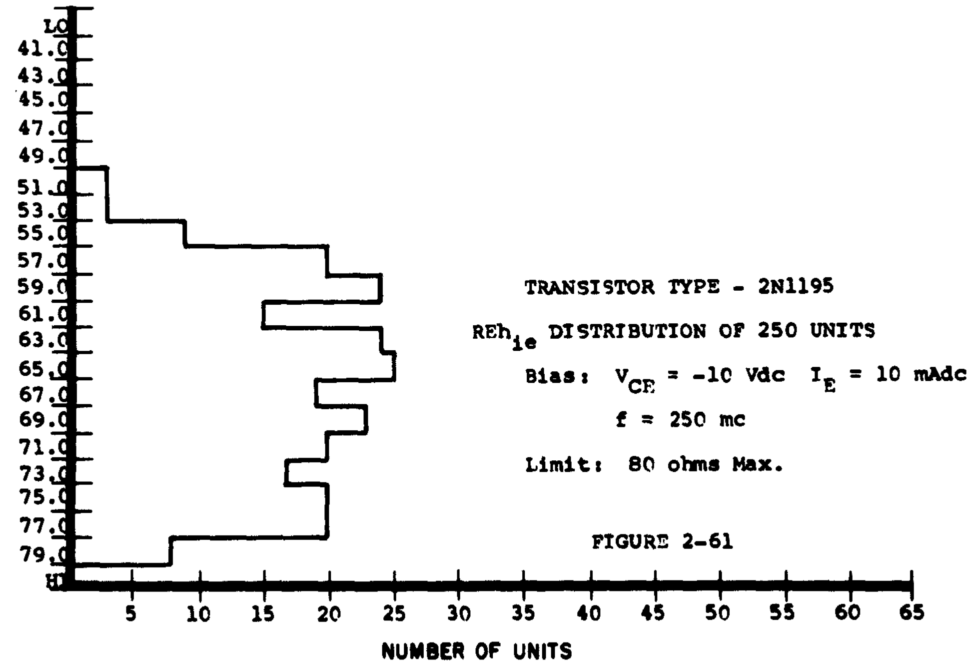
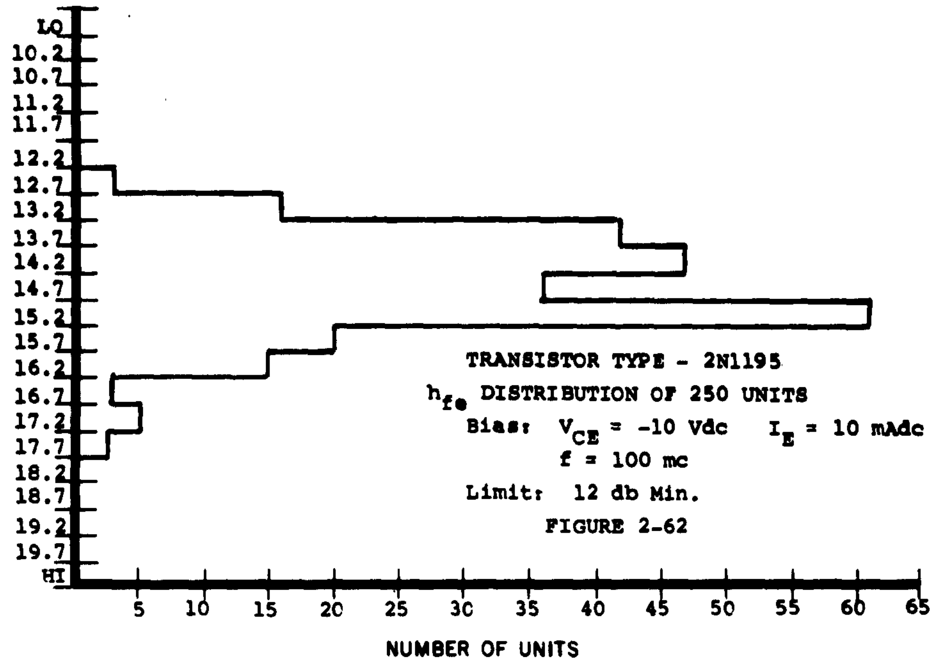
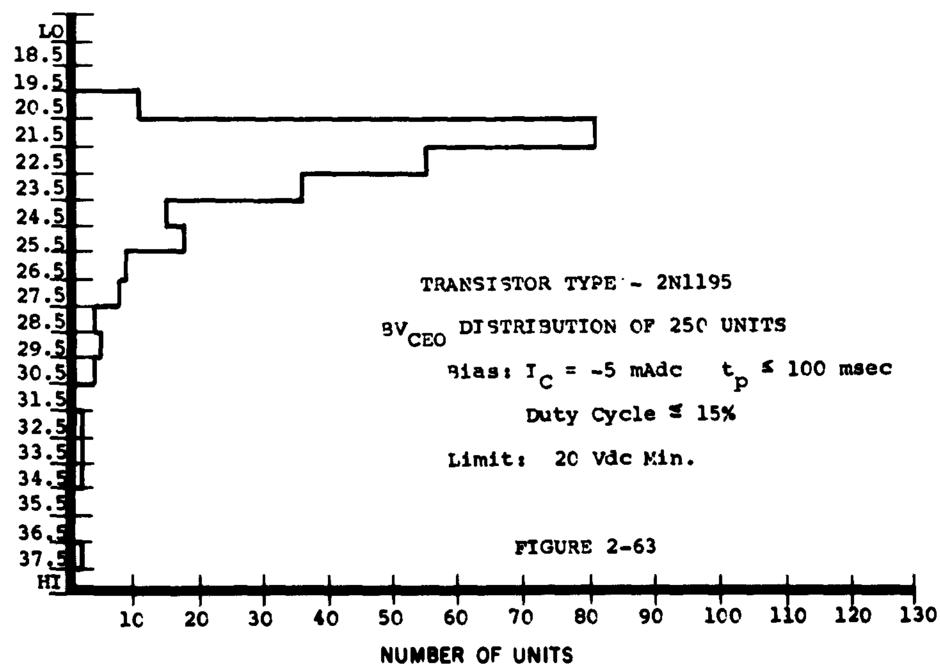


FIGURE 2-61


LO
10.2
10.7
11.2
11.7
12.2
12.7
13.2
13.7
14.2
14.7
15.2
15.7
16.2
16.7
17.2
17.7
18.2
18.7
19.2
19.7
HI
TRANSISTOR TYPE - 2N1195
h_{fe} DISTRIBUTION OF 250 UNITS
Bias: V_{CE} = -10 Vdc I_E = 10 mAdc
f = 100 mc
Limit: 12 db Min.
FIGURE 2-62
5 10 15 20 25 30 35 40 45 50 55 60 65
NUMBER OF UNITS


LO
18.5
19.5
20.5
21.5
22.5
23.5
24.5
25.5
26.5
27.5
28.5
29.5
30.5
31.5
32.5
33.5
34.5
35.5
36.5
37.5
HI
TRANSISTOR TYPE - 2N1195
BV_{CEO} DISTRIBUTION OF 250 UNITS
Bias: I_C = -5 mAdc $t_p \leq$ 100 msec
Duty Cycle $\leq$ 15%
Limit: 20 Vdc Min.
FIGURE 2-63
10 20 30 40 50 60 70 80 90 100 110 120 130
NUMBER OF UNITS

SUMMARY OF 2N559 PILOT RUN GROUP B INSPECTION

EXAMINATION OR TEST	End Point Tests	Lot No.	No. in Sample	No. of Failures Minor	No. of Failures Major	Failur- Permitt Minor	M
Subgroup 1							
Physical Dimensions	None	185P	78	0	0	7	
		187P	78	0	0		
		188P	78	0	0		
Subgroup 2							
Moisture Resistance	I_{EBO}	185P	266	0	0	2	
	I_{CBO}	187P	266	0	0		
	h_{FE}	188P	266	0	0		
Subgroup 3							
Tension							
Solderability	I_{EBO}	185P	78	0	0	2	
Temperature Cycling	I_{CBO}	187P	78	0	0		
Thermal Shock	h_{FE}	188P	78	0	0		
Moisture Resistance							
Subgroup 4							
Shock							
Constant Acceleration	I_{EBO}	185P	78	2	0	2	
Vibration Fatigue	I_{CBO}	187P	78	1	0		
Vibration, Variable Freq.	h_{FE}	188P	78	0	0		
Subgroup 5							
Terminal Strength - Lead Fatigue	None	185P	78	0	0	2	
		187P	78	0	0		
		188P	78	0	0		
Subgroup 6							
High Temperature Life (Non-Operating)	I_{EBO}	185P	1152	0	0	2	
	I_{CBO}	187P	1152	0	0		
	h_{FE}	188P	1152	0	0		
Subgroup 7							
High Temperature Life (Non-Operating)	I_{EBO}	185P	231	0	0	3	
	I_{CBO}	187P	231	0	0		
	h_{FE}	188P	231	3	0		
Subgroup 8							
Steady State Operation Life	I_{EBO}	185P	116	0	0	2	
	I_{CBO}	187P	116	0	0		
	h_{FE}	188P	116	1	0		

FIGURE 2-64

SUMMARY OF 2N560 MECHANIZED RUN GROUP B INSPECTION

Lot No. 206 - 10,000 Devices

EXAMINATION OR TEST	End Point Tests	No. in Sample	No. of Failures	Failur Permitt
Subgroup 1				
Physical Dimensions	None	52	0	83*
Subgroup 2				
Soldering Temperature Cycling Thermal Shock Moisture Resistance	I_{CBO} $V_{CE(sat)}$ BV_{CES}	32	0	3
Subgroup 3				
Shock Constant Acceleration Vibration Fatigue Vibration, Variable Frequency	I_{CBO} $V_{CE(sat)}$ BV_{CES}	32	0	3
Subgroup 4				
Lead Fatigue	None	32	0	3
Subgroup 5				
Storage Life	I_{CBO} $V_{CE(sat)}$ BV_{CES}	105	0	2

* Demerits Permitted

FIGURE 2-65

SUMMARY OF 2N1051 MECHANIZED RUN GROUP B INSPECTION

Lot No. 82 - 2,350 Devices

EXAMINATION OR TEST	End Point Tests	No. in Sample	No. of Failures	Failures Permitted
Subgroup 1				
Physical Dimensions	None	52	0	83*
Subgroup 2				
Low Temperature Operation	h_{fe}	52	2	2
Subgroup 3				
Soldering Temperature Cycling Thermal Shock Moisture Resistance	I_{CBO} h_{fe} BV_{CES}	52	0	2
Subgroup 4				
Shock Constant Acceleration Vibration, Fatigue Vibration Variable Frequency	I_{CBO} h_{fe} BV_{CES}	52	0	2
Subgroup 5				
Lead Fatigue	None	52	0	2
Subgroup 6				
Storage Life	I_{CBO} h_{fe} BV_{CES}	105	0	2

* Demerits Permitted

FIGURE 2-66

SUMMARY OF 2N1094 MECHANIZED RUN GROUP B INSPECTION

Lot No. 58 - 2,000 Devices

EXAMINATION OR TEST	End Point Tests	No. in Sample	No. of Failures	Failures Permitted
Subgroup 1				
Physical Dimensions	None	52	0	87*
Subgroup 2				
Soldering Temperature Cycling Thermal Shock Moisture Resistance	I_{CBO} h_{fb}	32	0	3
Subgroup 3				
Shock Constant Acceleration Vibration Fatigue Vibration Variable Frequency	I_{CBO} h_{fb}	32	0	3
Subgroup 4				
Lead Fatigue	None	32	0	3
Subgroup 5				
Thermal Resistance	θ_{J-A}	32	0	3
Subgroup 6				
Storage Life	I_{CBO} h_{fb}	52	0	2

* Demerits Permitted

FIGURE 2-67

SUMMARY OF 2N1195 MECHANIZED RUN GROUP B INSPECTION

Lot No. 160 - 2,000 Devices

EXAMINATION OR TEST	End Point Tests	No. in Sample	No. of Failures	Failures Permitted
Subgroup 1				
Physical Dimensions	None	52	0	87*
Subgroup 2				
Soldering Temperature Cycling Thermal Shock Moisture Resistance	I_{CBO} h_{fb}	32	0	3
Subgroup 3				
Shock Constant Acceleration Vibration Fatigue Vibration Variable Frequency	I_{CBO} h_{fb}	32	0	3
Subgroup 4				
Lead Fatigue	None	32	0	3
Subgroup 5				
Storage Life	I_{CBO} h_{fb}	52	0	2

* Demerits Permitted

FIGURE 2-68

MACHINE REFERENCE NUMBERS

PEM CONTRACT DA-36-039-SC-72729

CONTRACT ITEM NO.	MACHINE	WECO DRAWING NUMBER	OPERATING & MAINTENANCE SPEC. NO.
6-2-1	Cleaning Header Lead Wire	C-281603	21952
6-2-2	Piece Part Cleaning	C-281625	21914
6-2-3	Piece Part Gold Plating	C-281709	21968
6-2-4	Platform Lead Welding	C-281580	21943
6-2-5	Header Assembling	C-281584	21908
6-2-6	Header Glassing	C-281710	21951
6-2-7	Header Lead Trimming	C-281586	21909
6-2-8	Strip Perforating & Welding #1	C-281601	21911
	Strip Perforating & Welding #2	C-281601	21911
6-2-9	Header Continuous Rack Plating	C-281602	21912
6-2-10	Can Getter Assembling	C-281676	21956 21958
6-2-11	Slice Scribing	C-281597	21910
6-2-12	Wafer Breaking, Screening & Loading	C-281690	21915
6-2-13	Wafer Bonding	C-281596	21913
6-2-14	Wire Bonding #1	C-281674	21937
	Wire Bonding #2	C-281664	21938
6-2-15	Final Cleaning	C-281606	21936
6-2-16	Closure Welding	C-281663	21950
6-2-17	Card Loading	C-281669	21940
6-2-18	Testing & Date Stamping - 2N559	SID-306273 C-281623	21948
6-2-19	Data Handling	SID-306411 SID-306493	21959
6-2-20	Card Packaging	C-281662	21939

FIGURE 2-69

SECTION 3

MECHANIZED OPERATIONS

This section contains narratives on each of the 20 mechanized operations developed during Phase 1 of the Contract. An additional narrative reviews development of tooling for a Can Punching and Coding operation. Each narrative contains a description of the prototype machine as well as a review of its development, operational problems, and performance. The Strip Perforating and Welding and the Wire Bonding narratives also review development of one extra machine for each operation.

As stated earlier, reductions in production requirements made it feasible to combine the mechanized production lines being provided under this Contract and Contract No. DA-36-039-SC-81294. The following machines of the latter Contract can be used for 2N559-2N1094 production as well as 2N560-2N1051-2N1195 production of that Contract:

Operation	No. Machines
Cleaning Header Lead Wire	1
Wafering	2
Wafer Screening	1
Wafer to Header Bonding	2
Painting and Coating	1
Coding	1
Packing	1

Nests and header handling mechanisms on the above Wafer to Header Bonding Machines must be changed whenever 2N559 or 2N1094 production is to be run. Similar changes must be made on the Painting and Coating and the Coding Machines before processing 2N559 or 2N1094 transistors. These changes are necessary because 2N559 and 2N1094 transistors are TO-18 devices and 2N560, 2N1051, and 2N1195 transistors are TO-5 devices.

Since the original method of identifying 2N559 transistors was unsatisfactory and transistor production requirements were reduced, the Coating Machine designed to apply a protective finish to 2N559 transistors was deleted from this contract. All finishing and coding of 2N559 and 2N1094 transistors will now be performed on the Painting and Coating and the Coding Machines developed under Contract No. DA-36-039-SC-81294.

A recent proposal to modify the contract, technically accepted December 19, 1962, changed the title of the Card Trimming and Packaging Operation to Card Packaging. This proposal also deleted the Testing and Date Stamping Operation for 2N1094 and 2N1195 transistors, and transferred Can Punching and Coding from the list of machines to the Special Tooling and Test Equipment category. A commercial punch press is used for Can Punching and Coding; only special tooling for this operation was developed under the Contract. A narrative on this development is included in this section inasmuch as considerable effort was expended perfecting tooling for code embossing. Narratives in the following subsections cover all mechanized equipment completed by December 31, 1962 as contracted in the proposed contract modification technically accepted.

SECTION 3.1

CLEANING HEADER LEAD WIRE

R. W. Ingham

Q. L. Schmick

CLEANING HEADER LEAD WIRE

I General

The Cleaning Header Lead Wire process is used to prepare precut lead wires for subsequent glass-to-metal sealing. To effect a reliable seal, it is necessary to remove all foreign matter from the surface of the lead and to remove the impurities from the surface straits of the material. Although the sealing process requires an oxide layer on the lead, Header Glassing developments during Phase 1 led to eliminating lead oxidizing on this machine. Mechanization of the Header Assembly Operation, however, necessitated two additional requirements-the removal of burrs and the maintenance of straight leads.

Leads provided by manual processing became bent during processing and the resulting product was not suited for the mechanized Header Assembling operation. Since a very high percentage of the manually cleaned leads had camber which hampered the performance of subsequent mechanized equipment, it became necessary to find a different process. With the introduction of electropolishing on the Cleaning Header Lead Wire Machine, the burr is removed and lead straightness is maintained. At the same time, the rate was increased and the yield was improved.

II Description of the Machine

All operations are performed in stations located around a single turret continuous motion machine (Figure 3.1-1). The drive consists of a 1/2-horsepower motor driving a pulley located on the lead loading station (Figure 3.1-2) through a variable speed drive and a 600 to 1 reductor. Timing belts, used in conventional fashion, connect the various components to the driver pulley. A special length and width timing belt used in reverse fashion connects the driver pulley through a series of idler pulleys to the turret. The lead feeding drum is driven from an auxiliary pulley on the main drive through a spring plunger clutch. The diameter of the driver pulley is machined specially so that the resulting belt and turret speed is the same as the speed of the leads in the slotted drum. Thus, on the lead loading station (Figure 3.1-3) when the belt, turret, and leads in the drum are all mutually tangent at the point of transfer, there is no relative motion between these components.

Precut leads are degreased prior to delivery to the machine. The operator loads bundles of 3000 leads vertically in the hopper of the loading station (Figure 3.1-2). A duplicate hopper is provided so that one can be loaded while the other is in operation. The pusher forces the leads to spread out across the serrated face of the drum. As the drum rotates, the leads are forced into the slots one-at-a-time and are allowed to escape from the pack. They are transported around to the periphery of the turret where the belt then transfers and clamps the leads to the turret (Figure 3.1-3).

The electropolishing or cleaning is performed at the next station. The electropolishing solution presently being used is Battelle Super Surfacing Electropolishing Solution, but other solutions could be used. The cleaning tank was fabricated from Carpenter #20 stainless steel because of its resistance to corrosion in the presence of sulphuric acid.

The tank is constructed to allow the entry of the lead through a weir with from 1/4 to 3/4 inch of the lead immersed. As a small amount of acid spills over the entrance and exit weirs, it empties into an outer-shell type tank where it is heated and recirculated. During the recirculation cycle, the acid passed over a heat exchanger which serves a dual purpose that of cooling the acid and heating the rinse water. When the lead contacts the acid, which is between 55 and 60°C, electrolytic action starts. Since the lead is used as the anode, its diameter is reduced between .0006 and .0008 of an inch. Passing through the exit weir, the lead continues to the rinse station.

The rinse tank, which is designed with the same type of weir, maintains a liquid level approximately 1/4 inch higher than in the acid tank to assure that the entire electropolished area is rinsed.

Passing through the exit weir, the lead enters a spray rinse chamber. Here heated water is pumped through spray nozzles onto the leads. The impinging action of the spray loosens adhering residue and rinses it away. After rinsing, the lead is transported to the drying station where heated dry air is blown against the leads to remove excessive water. Infrared lamps are used to complete the drying at this station. The air nozzles and the lamps are enclosed to prevent rinse water from being blown about.

As the lead continues, it passes through the oxidizing station, an optional operation. At this station, radio-frequency energy is used to heat the lead. The lead is heated in the atmosphere where oxygen is extracted to form the oxide. The radio-frequency generator is placed alongside the machine adjacent to the work coil which is water cooled and shaped to fit the curvature of the turret. Two heating plates, which are also shaped to the curvature of the turret, are heated by the radio-frequency coil. This heat is then transferred by radiation to the lead as it passes between the plates. As the leads leave this station, they pass a sensing switch connected to a Veeder-Root impulse counter (Figure 3.1-4) and then continue to the unloading station.

At the unload station the belt is removed from the periphery of the turret by the belt roll. This releases the lead and allows it to fall through the unload tube into one of the lead bins. Since all leads fall with identical orientation, no special effort is required to orient them for use in the mechanized Header Assembling operation. When 3000 leads have been counted, an empty bin is indexed to a point directly under the feed tube. The operator removes the end or the full bin and places the leads in a storage bottle which is delivered to the Header Assembling Machine.

Both the mechanical and the electrical systems utilize well-known techniques to mechanize this operation. Because the acid is especially corrosive, special materials are used to handle it.

The operator's duties are to load and unload the machine and machine surveillance, especially temperature and concentration of the acid. The control panel which is within easy reach of the operator houses the gages and indicator lights which denote the condition of the machine.

III Machine Development

When this process was done manually, a decarburization furnace was used which necessitated seven operations - unload bottle, load basket, orient leads in basket, load basket in furnace, decarburize, separate leads and orient to load bottle. (Figure 3.1-5 graphically illustrates the mechanized and manual process.) The degreased leads were delivered to the decarburization furnace in storage bottles containing approximately 3,600 leads. They were unloaded from the bottle and divided into four stainless steel wire baskets. The baskets were then loaded into a manually fed furnace. After approximately 30 minutes exposure to the hydrogen atmosphere in the furnace, the baskets were manually moved to a cooling area near the unloading end of the furnace. When the baskets were properly cooled, they were pulled from the furnace and the leads were piled on a work table. Operators would then separate the leads and repack them in clean bottles for transfer to the oxidation operation. Since the temperature for the decarburization process was 1100°C, most of the leads would warp due to relief of the working stresses in the material, and some would stick together. When the operator separated the stuck leads, additional bending often occurred. The combined rate was 2600 leads per hour including bent or warped leads. The bent and warped leads rendered the entire lot useless in the automatic lead feeders of the Header Assembly Machine, but were usable for manual assembly.

To extend the use of the mechanized equipment, the primary objective was to find a process which would limit the deformation of leads during cleaning and oxidation. There was also a secondary objective of burr removal. These two objectives were accomplished by a process known as "electropolishing." This process can be compared to reverse electroplating. In this machine the lead becomes the anode which transfers ions into the acid solution and, subsequently, to a cathode which is the tank itself. The rate at which leads are processed is a direct function of current concentration and time of exposure.

During the development a small tank was made to determine the feasibility of the electropolishing technique. Although these leads were done on a batch basis, the results obtained were very encouraging and we could foresee a way of combining lead cleaning with a machine controlled oxidizing operation. The combined operations eliminated most of the manual handling and, in turn, eliminated the cause of bent leads. Later developments in Header Glassing, Section 3.6, eliminated the need for pre-oxidation.

IV Operational Problems

During prove-in the heating plates, which are used as a mass to create a magnetic couple, warped and arced across either the leads or the radio-frequency coil. Arcing across the leads caused no major problems, but arcing to the coil caused the water-cooled coil to leak. After approximately three weeks of continued heating, the plates became annealed and warping stopped.

Another problem involved the drum of the lead loader. The leads would not fit into the serrations of the drum since there were burrs on the ends. An undercut, added to the drum in the zone where burrs would touch, improved lead feeding; however, a more significant improvement was noticed after the lead supplier decreased the size of the burrs.

After the prove-in phase, this machine was installed in the production area for shop trial runs. Shortly after this, the lead length was shortened one inch. New weirs were added to the tanks to raise the liquid levels, and spacers were used to elevate the radio-frequency coils to the appropriate height. Also at this time, developments of Header Glassing proved conclusively that pre-oxidation before assembly was not necessary to make a good glass-to-metal seal. Since clean, straight leads are still necessary, the machine has been running its production trials without using the oxidation station.

During the shop trial period a new problem was encountered involving a high carbon content in the material from which the leads were made. Since the electropolishing cycle was set to remove a given amount of material, the excessive carbon was not entirely removed. The residual carbon was later removed as gas during the glassing operation and caused bubbles in the glass. To remedy this, we changed the material specification to use a vacuum melted alloy with a lower limit on carbon.

The pilot run was completed in a period of three months. During this time 1,500,000 leads were processed at an average rate of 4500 leads per hour. Although the yield was high, there were some rejects due primarily to handling. There were no piece part problems. The only maintenance involved was the replacement of two infrared drying bulbs, and changing 15 gallons of acid each 300,000 leads.

V Evaluation

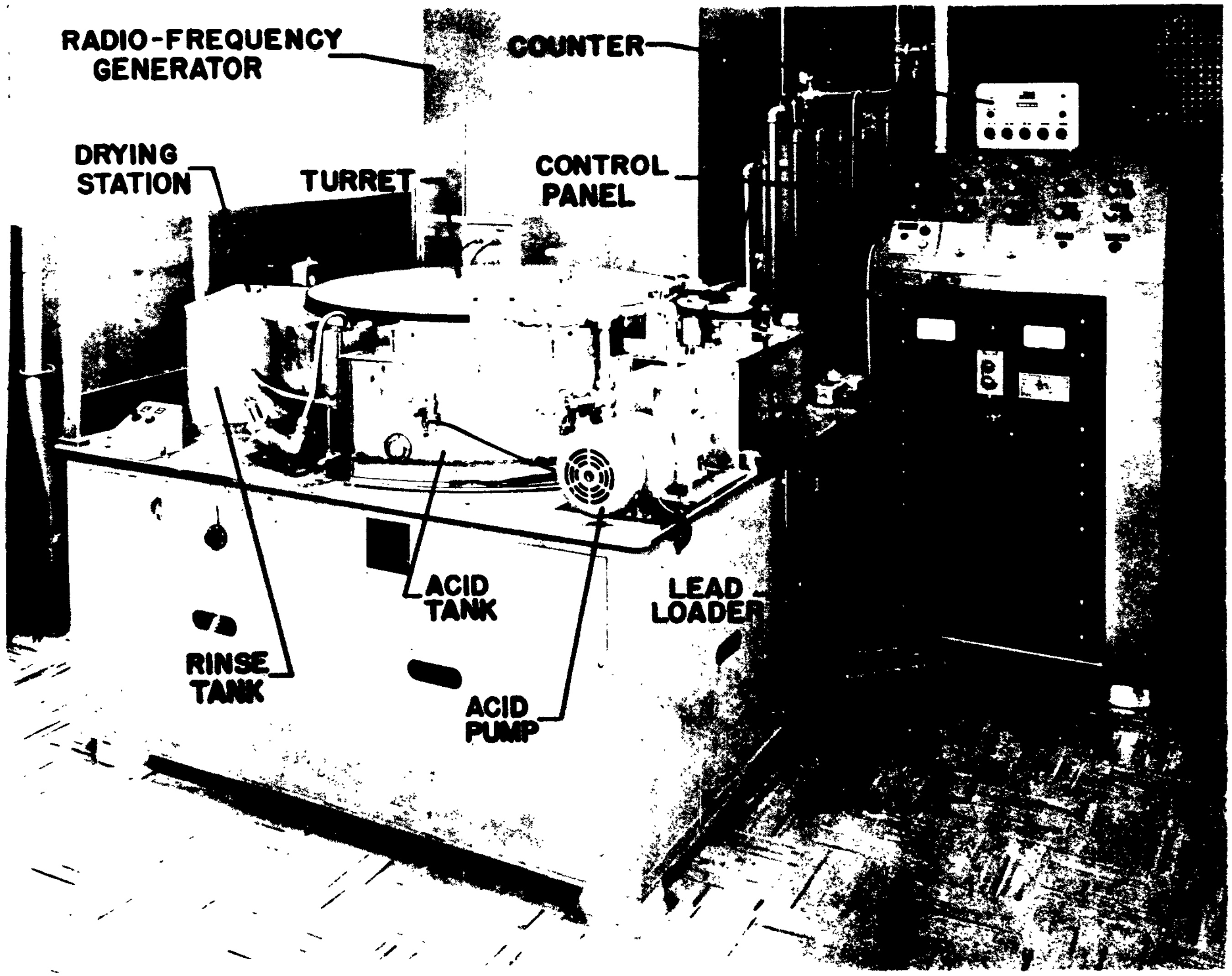
The mechanical and electrical systems are very reliable, thus, the machine is virtually maintenance free. This machine has operated continuously on a 2-shift basis with no repairs or excessive maintenance. Although a 3-shift trial has not been made, it appears that the same reliability could be expected. After the operator becomes adjusted to the use of this machine, the major duties are those of loading and unloading leads.

The outstanding characteristic of this machine is the introduction of an improved lead cleaning process. Although the basic technique is not new, the electropolishing procedure has presented a faster and cleaner method of preparing leads. This is evidenced by the deletion of the handling operations and by the elimination of the furnaces shown in the Flow Diagram of Figure 3.1-5.

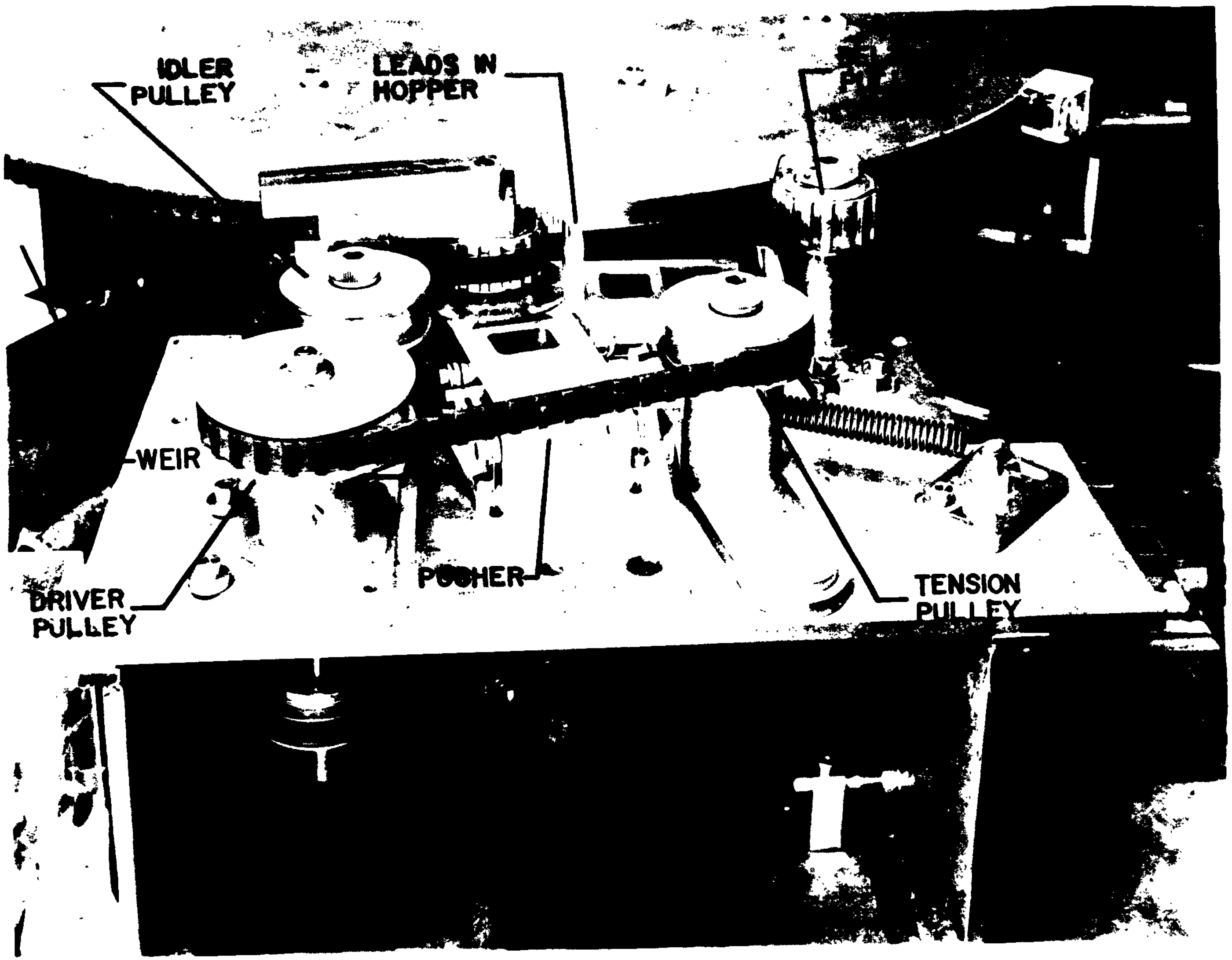
VI Conclusion

Insofar as this machine has sustained a consistent yield at a gross rate of 6000 leads per hour, the original expectations have been fulfilled. More important, however, the removal of both the burr and preservation of lead straightness have enabled unrestricted use of the Header Assembling Machine. In this respect, advancements are realized in that the net output of a single operator has been increased from 2600 pieces per hour to 4500.

Operation of the machine has greatly aided the mechanization of the Header Assembling operation and, in this respect, it has substantially increased the capacity of the transistor production line. An even more important development was the elimination of lead degradation as a result of repeated furnace operations at high temperatures. Improvements to the machine that might extend its useful life have been considered. One of these is coating of the lower acid tank with "Teflon" or similar materials. With present knowledge, it does not seem practical to increase production simply by increasing the size of the work table. (In Phase 2 we hope to increase the output by speeding up the entire machine). The process has demonstrated that it is capable of producing large quantities of cleaned leads compatible with the manufacture of bubble-free, clear glass-to-metal seals.



CLEANING HEADER LEAD WIRE MACHINE
FIGURE 3.1-1



LEAD LOAD STATION OF CLEANING HEADER LEAD WIRE MACHINE
FIGURE 3.1-2

FEEDING AND CLAMPING OF LEADS ON CLEANING HEADER LEAD WIRE MACHINE

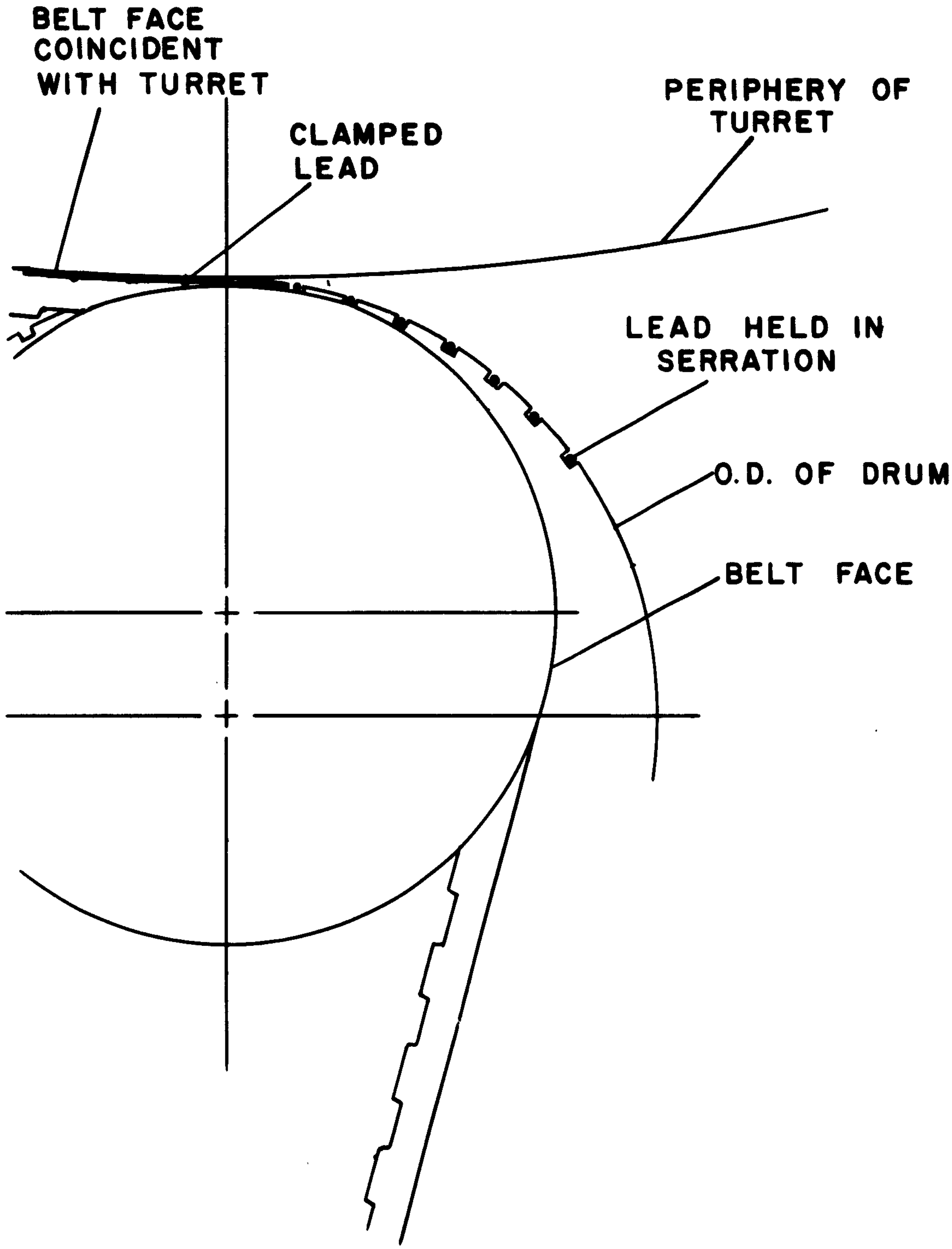
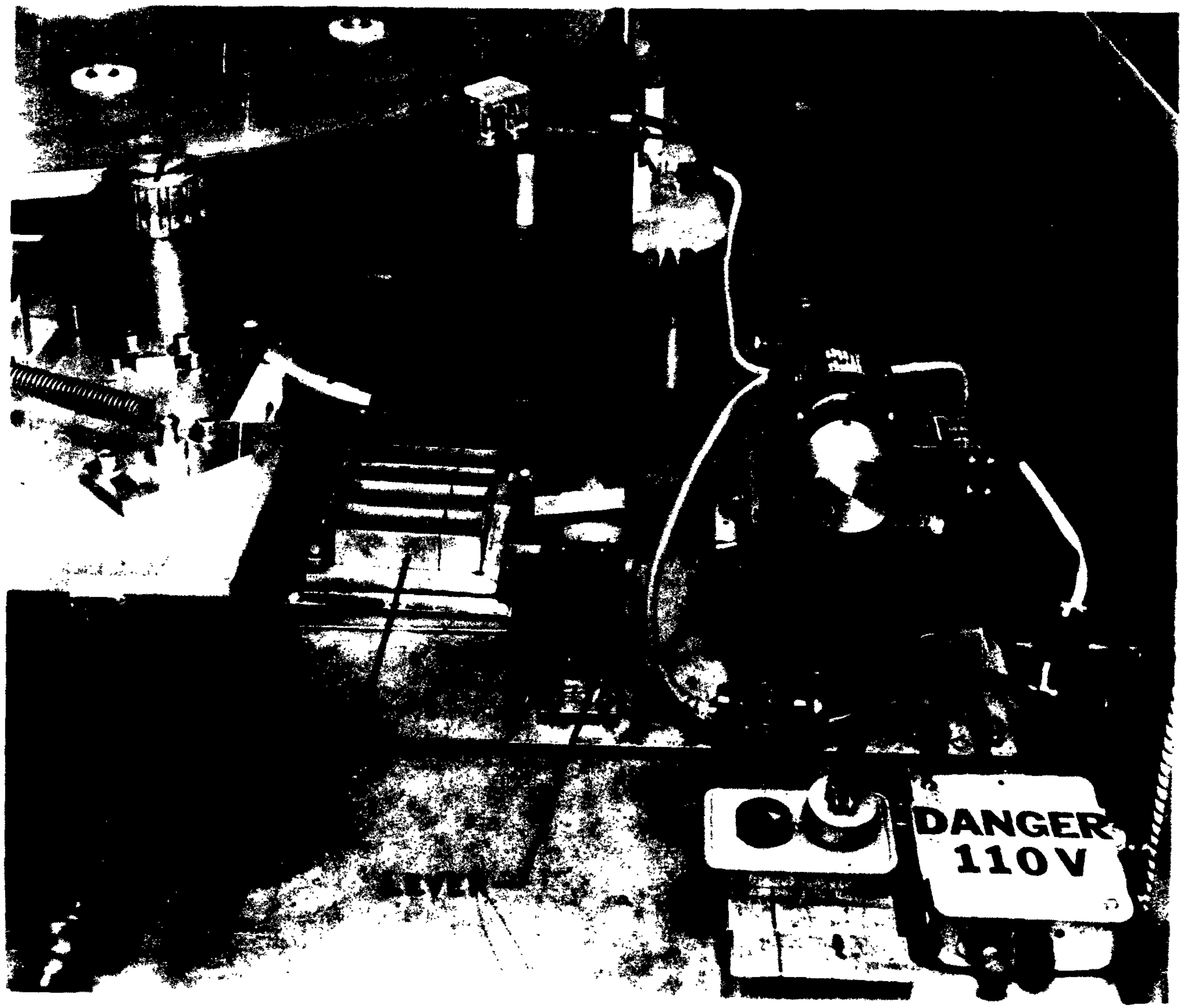


FIGURE 3.1-3



UNLOAD STATION OF CLEANING HEADER LEAD WIRE MACHINE
FIGURE 3.1-4

LEAD CLEANING PROCESSES

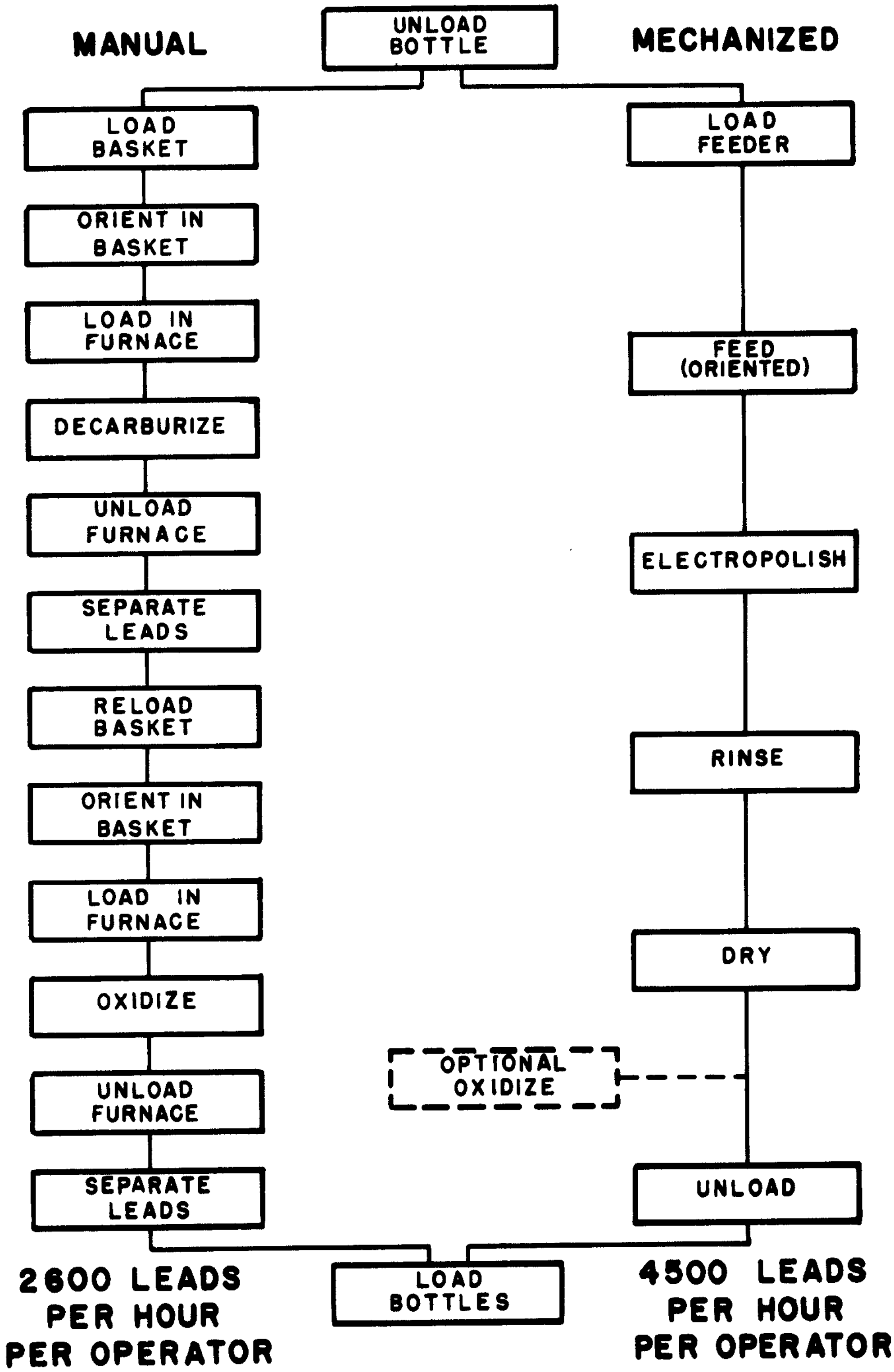


FIGURE 3.1-5

SECTION 3.2

PIECE PART CLEANING

R. P. Loeper

F. J. Reinhard

PIECE PART CLEANING

I General

The Piece Part Cleaning Machines were built to provide a means for mechanically moving batches of parts in small dipping baskets through a series of tanks. Two of these machines have been built to fulfill the program. Originally it was planned to have one machine clean ferrous parts, and the other machine non-ferrous parts. Difficulties that were encountered during the project and changes in the piece part requirements resulted in both machines being built to clean ferrous parts.

The machines replace an unmechanized process where an operator would transfer parts manually on a timer signal from tank to tank, and finally to a commercial dryer. The most difficult problem encountered during the project was the high corrosion rate of machine parts caused by the chemicals used. With the current 5-minute time cycle used for cleaning parts, the greatest advantage in the use of the machines is the more consistent cleaning of parts due to uniform timing. Further development of these machines would, for the most part, be in the field of corrosion resistance since corrosive agents and corrosive atmosphere in and around the machines have deteriorated some of the components.

II Description of the Machine

The Piece Part Cleaning Machines are built to provide a means for the mechanical handling of batches of parts in 6-inch dipping baskets through a series of tanks. Here the parts are successively degreased, pickled, etched, rinsed and dried prior to the application of a plated finish or assembly. The machines are generally of steel construction, protected by five coats of "Ucilon" vinyl coating. Each machine consists of four modules, a drive system and processing tanks. The remaining equipment consists of auxiliary tanks, heating and cooling coils, pumps, filters, exhausts, loading and unloading stations, and an electrical control system. This equipment is handled as optional attachments to the modules. Each set of four module machine covers an area 3 feet wide and 20 feet long; its control cabinet covers an area 1 foot by 3 feet.

Figure 3.2-1 is a general view of a machine showing the modules, exhaust system, steam and water services, and the electrical control cabinets in the background. Figure 3.2-2 shows the right side with pumps. Figure 3.2-3 shows the discharge end of the machine with a basket above the drying station, and Figure 3.2-4 shows the loading end module with guards removed to expose the vertical and horizontal drive mechanisms. These photographs were taken during installation and, as such, do not show the insulation on the steam pipes and complete exhaust system. These details do not detract from the finished effect and, in fact, tend to clarify some of the details of the machine.

To provide for anticipated process changes, the machine was constructed as four in-line modules having three stations per module. Modules are electrically interlocked for control purposes. Each module is composed of a frame, horizontal and vertical drive systems, exhaust plenum, and three exhaust risers. It is further divided into four horizontal levels. From top to bottom they are: (a) the work tanks; (b) horizontal and vertical drives; (c) space for auxiliary storage tanks and other attachments, and (d) the exhaust plenum. The exhaust risers attach to the plenum and extend vertically between work tanks to a position 2 inches above the lips of the work tanks.

The horizontal drive consists of transfer slides mounted along each side of the module. These transfer slides are driven by a motor powered gear reductor, two chain driven hexagonal shaped pinion shafts, one centered at each side of the frame, and an individual pinion gear sliding on the pinion shafts driving a rack attached to the transfer slides. Direction of slide travel is determined by direction of motor rotation. A single limit switch controls length and direction of travel.

The vertical drive raises and lowers the transfer slide assemblies. This drive consists of a motor driven gear reductor lead, driving four vertical lead screws by means of a chain. These lead screws are mounted at the four corners of the module; each of the lead screws drive a pair of nuts mounted in the transfer slide mechanism. Raising or lowering the transfer slides is dependent on the direction of motor rotation. A single limit switch once again controls both length and direction of travel. This drive causes the baskets to move in a rectangular path. All other elements needed to make the machine operable are built as attachments to the basic module.

There are 17 attachments currently available for use on the modules. From the list which follows, it will be apparent that only a limited number can be installed on any single module. This variety is provided to permit the process engineer to select components and, in some cases, components of special materials for the specific processing operation he wishes to perform. With the above limitation in mind, attachments may be interchanged between various stations of the modules. Auxiliary attachments for use with these modules are:

1. Loading station
2. Unloading station
3. Three fluid circulating systems
   a. "Hastelloy B"
   b. 304 Stainless Steel

c. 304 Stainless Steel with a filter added

4. Two steam heating systems

a. "Hastelloy B"

b. 304 Stainless Steel

5. Two work baskets

a. 5 x 6 inch rectangular

b. 6 inch diameter

6. Three work tanks

a. Hot rolled steel

b. 304 Stainless Steel

c. "Hastelloy B"

7. Drying Station

8. Polyvinyl chloride tank insert for hydrofluoric acid

9. Exhaust system

10. Parts agitator

11. Electrical System

The electrical system consists of an electrical control panel, all switch gear, wiring, limit switches, timers, and miscellaneous electrical equipment needed to make the machine operational. It is custom engineered for each machine or group of modules. If additional modules are to be added, this attachment must be modified accordingly. The two 4-module machines require the following services:

a. Electrical: 440 volt, 3 phase, 60 cycle, 45 amperes

b. Steam: 45 pounds per hour, 80% quality

c. Steam condensate drain

d. Acid drain: 480 gph

e. Tap water, hot: 330 gph at 140°F

cold: 120 gph at room temperature

f. Deionized water: 30 gph

g. Exhaust: 4500 cfm

The operator must turn on appropriate attachments and allow the machine half an hour to come up to operating temperature before placing it in operation. After warm-up, the operator turns on the remaining attachments and the machine commences to cycle. The operator must supply baskets to the loading station and remove completed work from the unload station. In addition, he must monitor the various solutions for concentration, make additions when needed, and check samples of finished parts for quality of cleaning. One man can operate both machines.

III Unmechanized Cleaning Process

The unmechanized process consisted of a commercial, manual, small parts cleaning and plating system of tanks, exhaust, pumps, filters, etc. The operator would manually transfer batches of parts through the various tanks and finally to a commercial dryer. At each tank he would set a timer and leave the work while attending to other duties. When the timer rang a bell, the operator would return and move the work to the next tank. Since all kinds of miscellaneous parts are cleaned on this equipment, the operator skips process tanks not called for in the manufacturing layout. The output is limited by the longest process time in any tank. Duplicate tanks for slow operations expedite cleaning large quantities of parts but process time variations still contribute to inefficiencies.

While process development was in a state of flux, the flexibility of the manual line was desirable. Once the process was stabilized, the emphasis shifted to efficiency and control of the cleaning process. Tank capacity was the main factor affecting efficiency. When batches of parts have unusually long cleaning times or times that are similar, machine cleaning is more efficient. The machine also gives much better control of the cleaning process as it automatically times immersion and removal of work from the tanks.

IV Machine Development

A special machine design was needed since no commercial equipment to meet our size requirements was available. Before engaging in the development of a special purpose mechanized cleaning machine, the possibility of obtaining a commercial machine was investigated. The size of regular commercial equipment would have made it possible to handle quantities of parts ten times greater than those we choose to process. In addition, our experience with the larger commercial cleaning and plating machines indicated a definite need to eliminate moving machinery from above the work tanks. The moving machinery above the tanks collected oil, dust and dirt which, in turn, fell into the work tanks and resulted in improperly cleaned lots of parts. The Piece Part Gold Plating Machine (Section 3.3) is representative of what was available and our experience with it was the underlying reason for seeking an alternate design. As an additional feature, the machine was designed and built to have unusual flexibility to accept changes in processing. Three such changes have been accomplished in the nine months since the machine was first installed.

At the time development of a special machine was undertaken, the device design was in a state of flux. This, in turn, reflected on ways and means of cleaning the parts so that problems in final assembly, testing, aging, and general device reliability could be minimized. Device reliability, in particular, is affected by dirt or contaminants. As a result, efforts were made to go to extremes of cleanliness at all production operations. Cleaning procedures were changed whenever theoretical or actual improvements could be made. Under these conditions, requirements were added so that the machine would be reasonably easy to modify for possible process changes.

The modular approach, with interchangeable attachments, was selected for ease of changing the machine. One module was then designed and built. As many of the attachments as would fit were crowded in it. It was impractical as a machine since it had only two useful work tanks, but did allow limited use. With it, .4 watt diode cases were alkali cleaned and rinsed. It was very useful as a "trial horse" since we had a working piece of equipment to locate the "bugs" in the drive mechanisms and attachments. The lead screws were particularly troublesome since slight misalignments caused immediate binding of the mechanism. As a result the frame and mounts were redesigned to overcome this fault. No corrosion data was collected on the experimental module since our experiments were limited to caustic cleaning.

As a background to the selection of structural materials, the equipment in service on our cleaning and plating line was reviewed. This review covered rubber lined tanks and piping, carbon heaters, tantalum heaters, ceramic crocks, and one "Hastelloy B" pump for hot hydrochloric acid. With the exception of tantalum, all these materials had limitations or histories of high maintenance which were undesirable.

"Hastelloy B" was selected since it was less expensive than tantalum, with the possibility that it would be less troublesome than the more conventional materials. The entire acid circulating system heaters, work tanks and everything that would be wetted by the acid - was made of "Hastelloy B". The alloy was expected to corrode at .005 inches per year for all elements in the system except the steam coil. This was expected to have a higher rate in the order of .024 to .040 inch per year because it would operate at 300°F. The material supplier's tests indicated a rate of .024 inch per year in boiling 20 percent hydrochloric acid. On the basis of this development, seven additional modules were made and the "trial horse" module modified. These eight modules were then assembled into two machines.

V Operational Problems

After installing both machines and connecting the piping and electrical controls, a full scale prove-in was started. The first problem encountered was trouble with "sticky" lead screws in the vertical drive system. The lead screw mounts had been redesigned after similar trouble with the experimental module. Despite an improved design, the subcontractor, who fabricated the frames for the seven remaining modules, rendered our efforts useless. Their final finish machining was performed with the frame in a warped position. To correct this condition, all the bearing housings had to be shimmed into position. This was as much, if not more of a problem, than the original design. After operating the mechanism for a few days the lead screws turned more freely. Several times after this the lead screws malfunctioned but each time adequate oiling and running the lead screws freed these drives.

The Piece Part Cleaning Machines were designed so that the pumps selected would circulate the solutions with such volume and velocity that agitation was considered unnecessary. In reality this did not occur. The geometry of the small parts was such that holes, blind corners, etc., did not clean up since fresh solution was not moving over these surfaces. This problem resulted in the addition of a parts agitation system. This system has a vertical amplitude of 1/2 inch and a frequency of 6 cycles a minute.

Corrosion of parts throughout the prove-in and operational runs has been a problem. Every effort was made in design to specify corrosion resistant parts; the machine also has, where practical, five coats of "Ucilon" vinyl for protection of parts. Except where punctured by accident, the resulting vinyl film has given excellent service. Touch-up, after machine changes, has taken care of damaged and punctured paint films. Sliding and moving metal parts have rusted where it was impractical to provide vinyl protection. Despite the poor appearance of these parts, oil or grease seems to give enough protection to keep them operating without need of repairs. The glands of the acid circulating pump had small leaks. This leakage corroded the ferrous screws holding the pump together and also caused a general housekeeping problem. Replacing the ferrous screws with "Hastelloy B" screws corrected this situation. No satisfactory solution has as yet been found to prevent the pump glands from leaking. Rinsing with water has kept the area under the pumps reasonably clean. The one item of the system affected most by corrosion was the steam coil in the acid bath. Steam coil failure is due to the high acid temperature at the surface of the coil. Coil failure was concentrated at points where supports were welded to the coils. New coils made of tantalum have been ordered to take care of this condition.

The original machine used plant compressed air for drying. This air did a satisfactory job on some parts, but on others it failed. A new dryer was designed that consisted of a blower and a heater stack. As the air passed through the heater stack, resistance heaters raised the temperature to approximately 180°F. This hot air is then channeled through the basket of parts to adequately dry them.

During prove-in and shop trial runs, two developments resulted in a major change in the use of the two machines. The first was the use of hydrofluoric acid on the machine. Originally it was hoped that glassed headers could be made with a short hydrofluoric acid etch before entering the cleaning cycle presented by the machine. However, introduction of the "Sealox" (Header Glassing) glass-to-metal furnace sealing process created a need for a more vigorous header cleaning process. Glass run-over on the piece parts was such that the etching time had to be extended. One machine was then converted to provide the more vigorous cleaning with the glass etch. To accommodate this process change, the tanks were re-arranged and the machine cycle changed from 2-1/2 minutes per tank to 5 minutes per tank, reducing output from 24 basket loads per hour to 12 loads per hour.

The second development ensued for two reasons. First, a design change was introduced changing the copper tubulated transistor can to a plain can, and secondly, copper parts drying was unsatisfactory. Design change of the piece part was a prime factor in reducing the need for the non-ferrous piece part cleaning machine because this markedly reduced non-ferrous cleaning requirements. Cleaning of copper parts from an appearance standpoint was disappointing. The machine dried parts had a tarnished appearance while the manually processed parts were very bright. This difference in finish was directly traceable to the different drying techniques used; hot water followed by hot air in the machine versus acetone then infrared heat for the manual process.

A series of tests indicated a slight decrease in brazing yield for the tarnished parts. Efforts to eliminate the cause of tarnished parts were unsuccessful. As a result of the drying problem, coupled with the need for more ferrous cleaning capacity and less non-ferrous capacity, the two Piece Part Cleaning Machines were set up to handle only ferrous parts. One machine with hydrofluoric acid etch for glassed assemblies, the other for plain ferrous parts. The smaller amounts of non-ferrous work are being processed on the manual line.

Maintenance for the first nine months of intermittent operation has been average for all elements except the "Hastelloy" steam coils and pumps. These have had a number of failures. The effects of hot hydrochloric acid on "Hastelloy B" were known before its selection. Aside from these and machine changes to accommodate process changes mentioned previously, the operation has been relatively trouble-free.

Since adding the hydrofluoric acid etch on the one machine, work requiring hydrofluoric acid dipping must be scheduled more carefully so that all parts, having the same process time cycle, are available to go through the machine in an orderly fashion. The time duration of the hydrofluoric acid dipping operation is particularly critical as the acid attacks the glass-to-metal seal. If a change in the process cycle is necessary, the operator allows 4 cycles to occur without loading parts in the machine. Then during this blank period, he resets the cycle timers while there are no parts in either the hydrochloric or hydrofluoric tanks. To date, there has been no need to vary the process cycle for non-glassed parts processed on the other machine. Glassed parts have a 5-minute cycle, non-glassed parts have a 2-1/2-minute cycle.

During the shop trials and the pilot runs, the operator has had an additional task of arranging the headers in the dipping baskets. This arranging consists of spreading the parts more uniformly throughout the basket thus lowering the height of the pile. The operator's duties are simple enough that he has sufficient time to operate both machines.

VI Evaluation

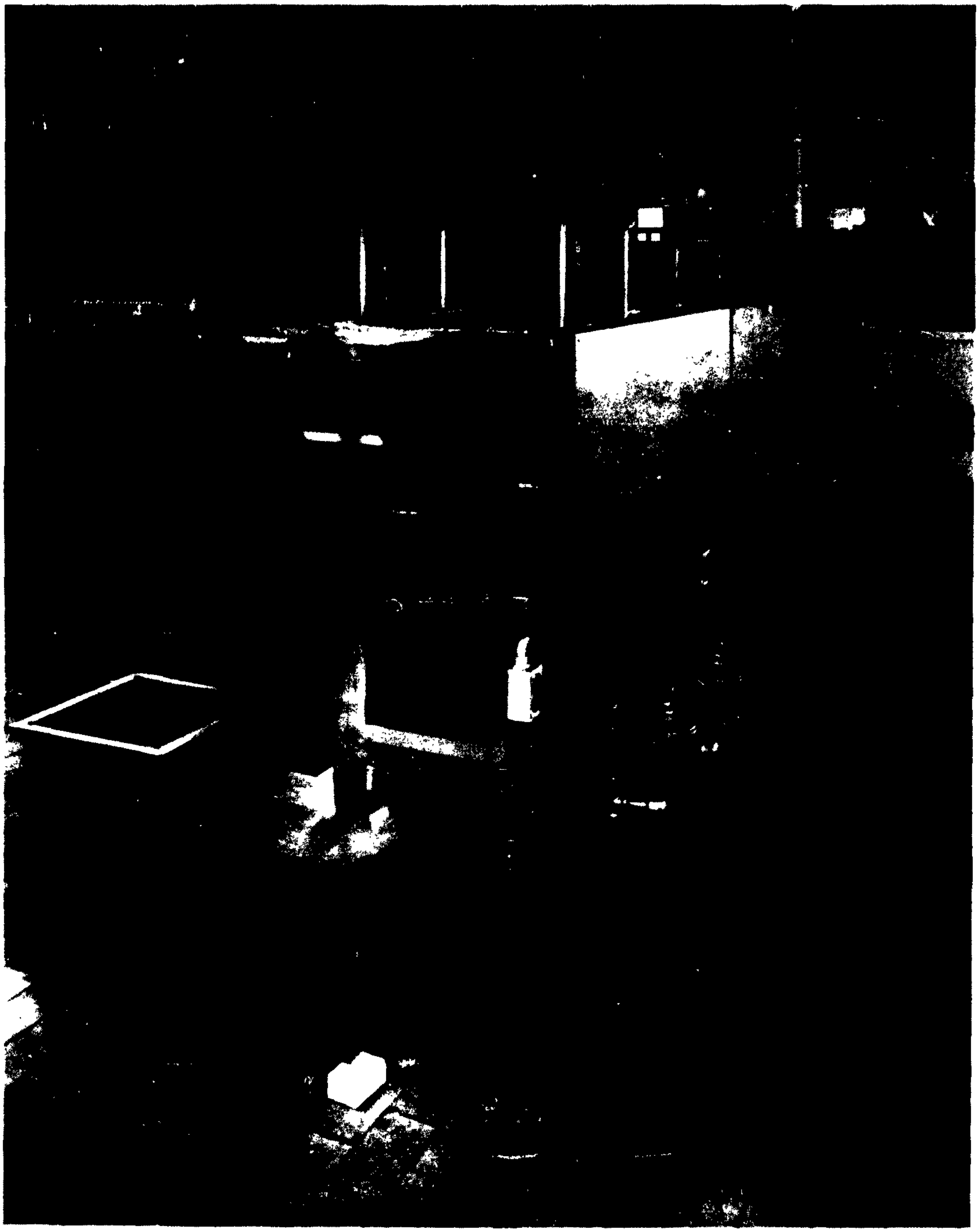
Two elements in the piece part cleaning systems were measured to evaluate the corrosion rate. These were the stand pipe in the work tank and the steam coil. After eight months of immersion, the stand pipe corroded approximately .003 inches and the steam coil approximately .033 inches. During this time the acid was at a working temperature of 150°F for approximately 180 hours.

Output of the machine processing glassed assemblies is 12 basket loads per hour. Output on the machine for plain ferrous parts is 24 basket loads per hour. These are double the rates for manual processing. Since size of parts varies so widely, quantities in a basket load vary from a low of 250 for TO-5 headers up to a high of 10,000 for leads. Further, these lot sizes are the same as would be used in manual cleaning. Therefore, in this case, output comparisons are based on basket loads rather than the more general practice of referring to specific parts. The quality of machine cleaned parts is more consistent due primarily to elimination of the human element.

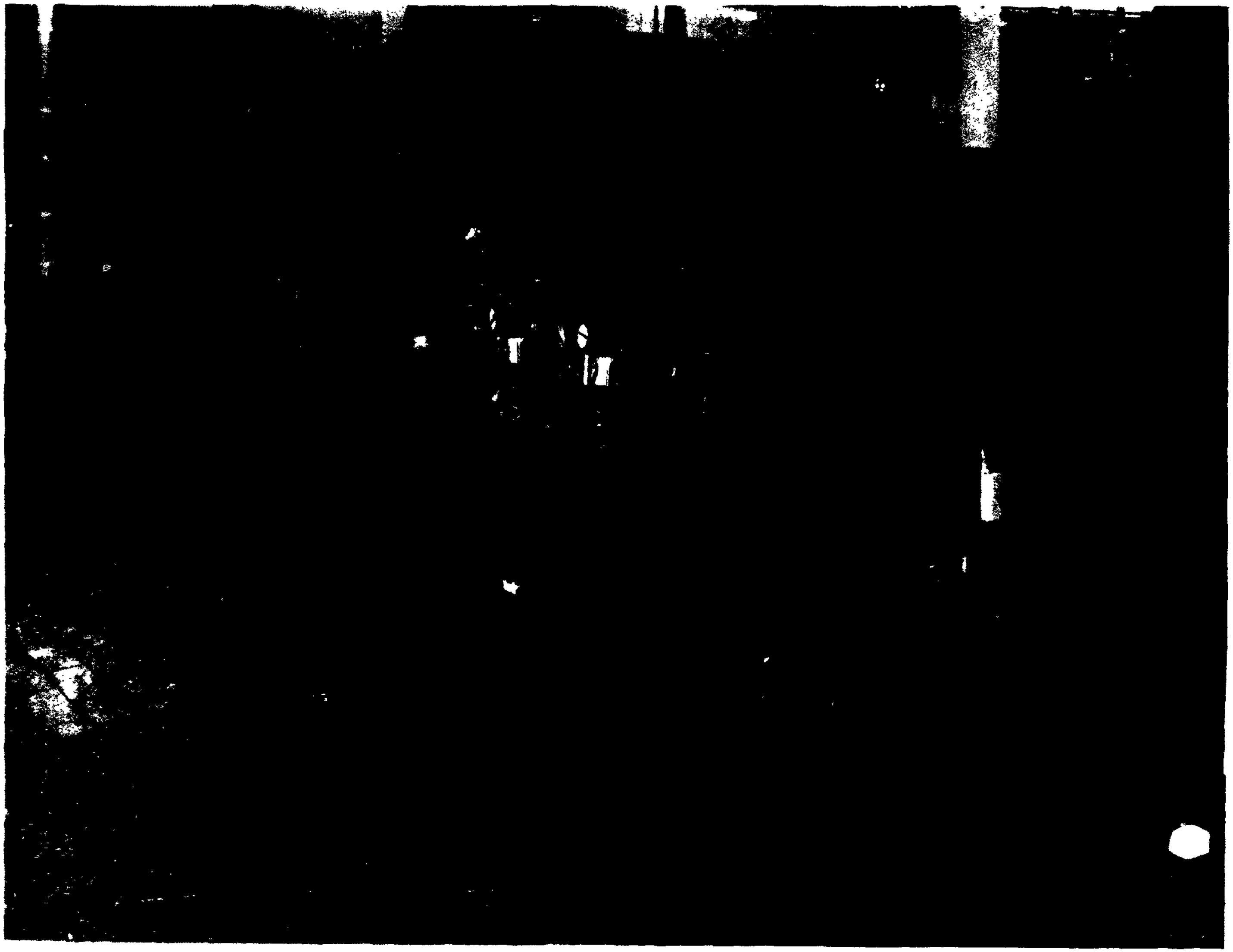
VII Conclusion

Headers and cans for the TO-5 and TO-18 transistor encapsulations constitute the bulk of the work to be cleaned by the Piece Part Cleaning Machine. Four-tenth watt diode cases comprise the next largest volume. Since these and all other parts normally processed are small, sizeable lots can be cleaned in small cleaning tanks: hence the need for a machine designed specifically for small parts cleaning. Flexibility was a requisite for process changes which may occur in the future. A minimum of overhead equipment was desired to keep the solutions as clean as possible since the cleaning requirements are critical.

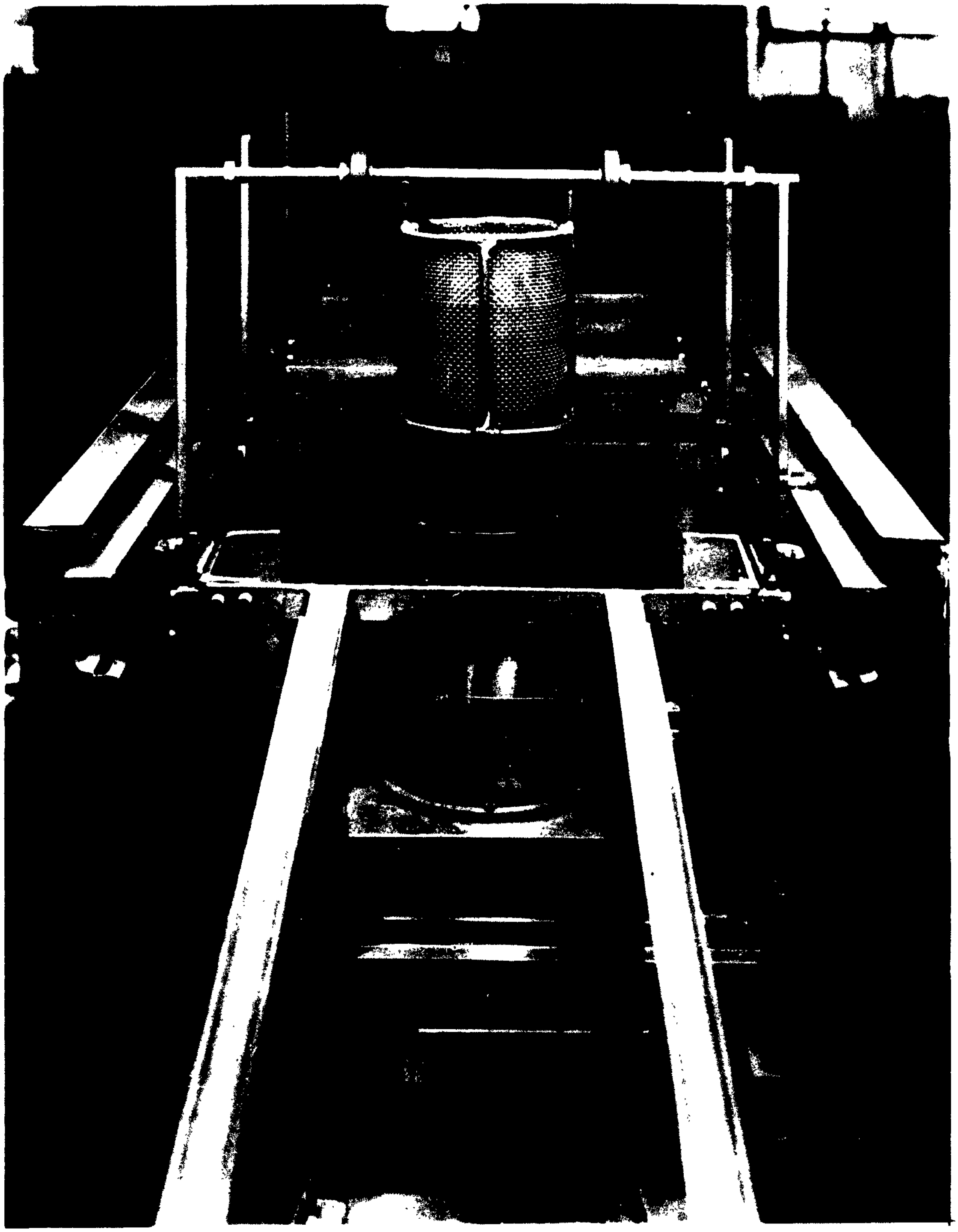
No machine was available commercially that offered the above features; therefore, the machine described in this report was provided. The lips of the exhaust system are the only part of the machine over the cleaning tanks. Processing tanks and associated equipment can be readily changed to meet any process variation. Parts can be cleaned on this machine in half the time required by manual cleaning. Based on the planning level for Nike Zeus production, the prototype equipment provided will have sufficient capacity to meet cleaning requirements for the program. Effort during Phase 2 will be made to improve corrosion resistance of component parts.



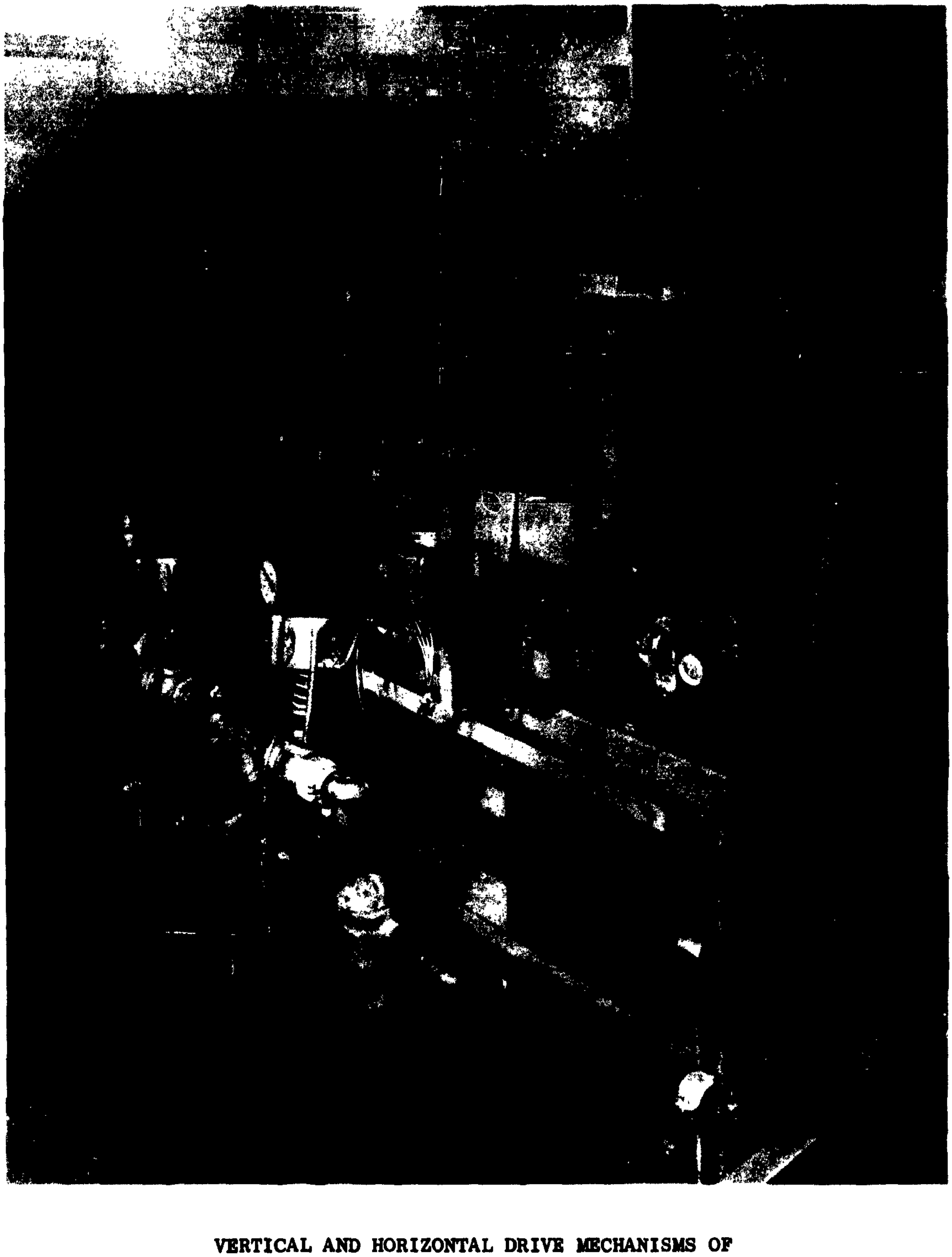
PIECE PART CLEANING MACHINE VIEWED FROM RIGHT
FIGURE 3.2-1



PIECE PART CLEANING MACHINE VIEWED FROM LEFT
FIGURE 3.2-2



DIPPING BASKET ABOVE DRYING STATION
OF PIECE PART CLEANING MACHINE
FIGURE 3.2-3



VERTICAL AND HORIZONTAL DRIVE MECHANISMS OF PIECE PART CLEANING MACHINE
FIGURE 3.2-4

SECTION 3.3

PIECE PART GOLD PLATING

C. P. Comins

PIECE PART GOLD PLATING

I General

An analysis of the proposed schedules and plating requirements of plated piece parts required for the 2N559 Transistor Program justified the development and procurement of a conveyor-type or automatic Gold-Plating Unit. The piece parts to be plated were the tubulated can and the 3-inch lead header assembly. Since the design of these assemblies was not yet firm, it was important that any gold-plating equipment developed be adaptable to meet any variations in the geometry of the piece parts and changes in the cleaning and plating cycles. This was in addition to the inherent problems of developing a machine capable of plating parts of significantly different geometries.

In the past excellent results were obtained in barrel plating a variety of piece parts including tubulated cans and headers of similar design except the length of the header leads was 1-1/2 inches instead of 3 inches.

On consideration of these factors, the decision was reached to develop and procure a general purpose automatic barrel plating machine capable of plating piece parts of various geometries and providing considerable flexibility in modifying or changing the cleaning and plating cycles. Then, if warranted by the geometry, quantity and/or final design of the piece parts, a special purpose plating machine would be developed. If required, the general purpose barrel plater would be available to process the parts in question during the design and prove-in periods of the special purpose machine.

An 8-station conveyorized barrel plating machine was developed and procured. Over a million tubulated cans were gold-plated with greater than 99 percent yield and headers were plated with an overall 90 percent yield. Developments in the requirements and design of the header assembly eventually indicated that a rack type plating machine was required for this assembly and the development described in Section 3.9, Header Continuous Rack Plating, was undertaken.

II Automatic Barrel Plating

From a study and analysis of the problems posed in gold-plating the tubulated can and header, it became apparent that initially a general purpose Automatic Barrel Plating Machine with the following features be procured to plate both parts:

1. To economically produce the quantity of parts required for the program with the quality specified.
2. Be capable of plating parts of various configurations.
3. Be flexible for changeover to different types of cleaning and plating baths.
4. Be adaptable for either barrel or rack use.
5. Have adjustable individual timer controls for the various baths.
6. Be compact, efficiently using the space occupied.
7. Be capable of being easily enlarged for increased production with little downtime and minimum cost.

The reasons leading to the above design criteria were:

1. Cleaning and plating processes initially specified were identical for both piece parts except for immersion time in the various baths.
2. The design for both parts was not firm and changes were

anticipated in the configuration of the parts as well as the cleaning and plating procedures.

3. Tubulated cans and headers of similar design (except the leads were 1-1/2 inches long instead of 3 inches) were successfully barrel plated.

After evaluating the automatic barrel plating equipment of several manufacturers, the machine finally purchased was an 8-station Abbey Process Automatic Single Barrel Plating System with several of our modifications. Stations were provided for the following operations:

1. Alkaline degrease and rinse.
2. Hydrochloric acid pickle and rinse.
3. Cyanide dip and rinse.
4. Copper plate and deionized water rinse.
5. Gold strike and gold plate.
6. Gold reclaim rinse.
7. Room temperature and hot deionized water rinses.
8. Loading and unloading stations.

By activating one button on the master control panel, a plating barrel is automatically conveyed from the loading station through the various cleaning and plating baths to the unloading station and stopped.

The machine is of a modular unit construction. Each self-contained module or station has identical frames, elevators, hydraulic lift cylinders, solenoid valves and limit switches, and are coupled to one another forming a closed continuous loop. Although each module is mechanically similar, their function can be altered by varying the interconnecting electrical controls.

The assembled unit is shown in Figure 3.3-1 with elevators in the down position. On the right is the ventilation system to exhaust the tanks, consisting of side draft exhaust hoods and risers manifolded into a common plenum chamber.

A typical cleaning cycle is as follows:

The cleaning and plating cycle is programmed into the master control panel (Figure 3.3-2) by setting the specified immersion times in the various baths on the respective timers. The master control button is then pushed which activates the series of controlling timers and relays. Once activated, the free wheeling carrier with an attached plating barrel (Figure 3.3-3) is conveyed from the loading station at the far end along the monorail trackway into the first station by the chain drive. The carrier is released from the chain drive at the end of the turn. At this point, the carrier activates a limit switch which causes the reciprocating overhead transfer bar to push the barrel to a predetermined position on the station elevator where another limit switch is tripped. The second limit switch activates a relay which starts the elevator containing the barrel downward into the first bath (typical descent, Figure 3.3-4). In its downward descent, bus bar contacts are made with a rectifier which provides direct current for cleaning or plating. Alternating current is provided through another bus bar contact to operate the motor drive which rotates the plating barrel. The barrel is lowered into the tank and remains there for the length of time preset on the particular timer in the master control panel. At the completion of the preset time, the timer activates a relay which starts the elevator upward. When the elevator returns to the monorail another limit switch is tripped which activates the overhead reciprocating transfer bar and pushes the barrel to the next station programmed in the master control panel. This procedure is repeated until the cycle is completed.

A safety interlock switch is provided to stop the reciprocating transfer bar from operating if the next station elevator is in a down position. This will prevent the carrier and plating barrel from being pushed into the open gap left in the monorail when the elevator is down.

The rectifier power supply and bath temperature controls in the rear of a typical station are shown in Figure 3.3-5. Also shown at the right rear of the rectifiers are the control buttons which can override the automatic controls and manually operate or by-pass the station if desired.

In addition, the following features were installed:

1. Continuous filtration systems for gold and copper cyanide baths.
2. Conductivity control in the rinse tank between the hydrochloric acid pickle and cyanide dip baths which prevents the transfer of the plating barrel to the cyanide tank until the parts are adequately rinsed, free of hydrochloric acid. This will prevent the accidental carryover of hydrochloric acid into the cyanide tank.
3. Ampere hour meter to control the amount of gold deposited on the piece parts.
4. Manual controls at each station that can override the automatic controls.
5. Individual temperature control of the various baths.
6. A ventilation system.

If it becomes necessary to enlarge the machine for increased production, additional stations can be added in the return loop. The machine can also be converted from a single to multbarrel unit. Another feature which can be added is a punch card system which will permit several barrels to go through the machine simultaneously, each with a different cleaning and plating cycle.

III Plating Barrels

Considerable effort was expended in evolving the final design of the two different internal cathode electrical contactor systems used to barrel plate the tubulated cans and headers.

The first Cathode Contactor System developed was for plating the tubulated cans. The initial design consisted of a stationary conducting centershaft shaped in the form of a hat section around which the barrel rotated. Freely hanging electrical conductors were attached to the uppermost section and dangled to the bottom of the barrel. The depth of immersion of the plating barrel was controlled to keep the uppermost section out of the plating solution, therby preventing a build-up of plate on the shaft.

Danglers in the form of chains, ball weighed chains and hair pin shaped danglers were investigated. In general, the danglers tended to ride on top of the work. As a result little or no current was led to the work. With this poor efficiency in the transfer of current, the gold-plate deposited was poor. We were unable to overcome the problems involved in having these flexible danglers continually buried in the work as necessary to improve the transfer of current and subsequently abandoned design effort in this direction.

The next system designed and procured was a stationary "comb" around which the horizontal barrel revolved. It consisted of a 3/4-inch stainless steel center shaft, drilled and tapped at 2-inch intervals for 1/4-inch stainless steel rods, the length of which came to approximately one inch from the bottom of the barrel. The entire unit was coated with a PVC (polyvinyl chloride) type plastic except for a 3-inch tip on each rigid rod dangler. For the first run, the danglers were positioned in a downward vertical position. However, the impact due to the momentum and weight of the cans bent the danglers. This obstacle was overcome by positioning the danglers 30 degrees from the vertical. With this arrangement, over a million tubulated cans in lot sizes of 10,000 were plated with a greater than 99 percent yield.

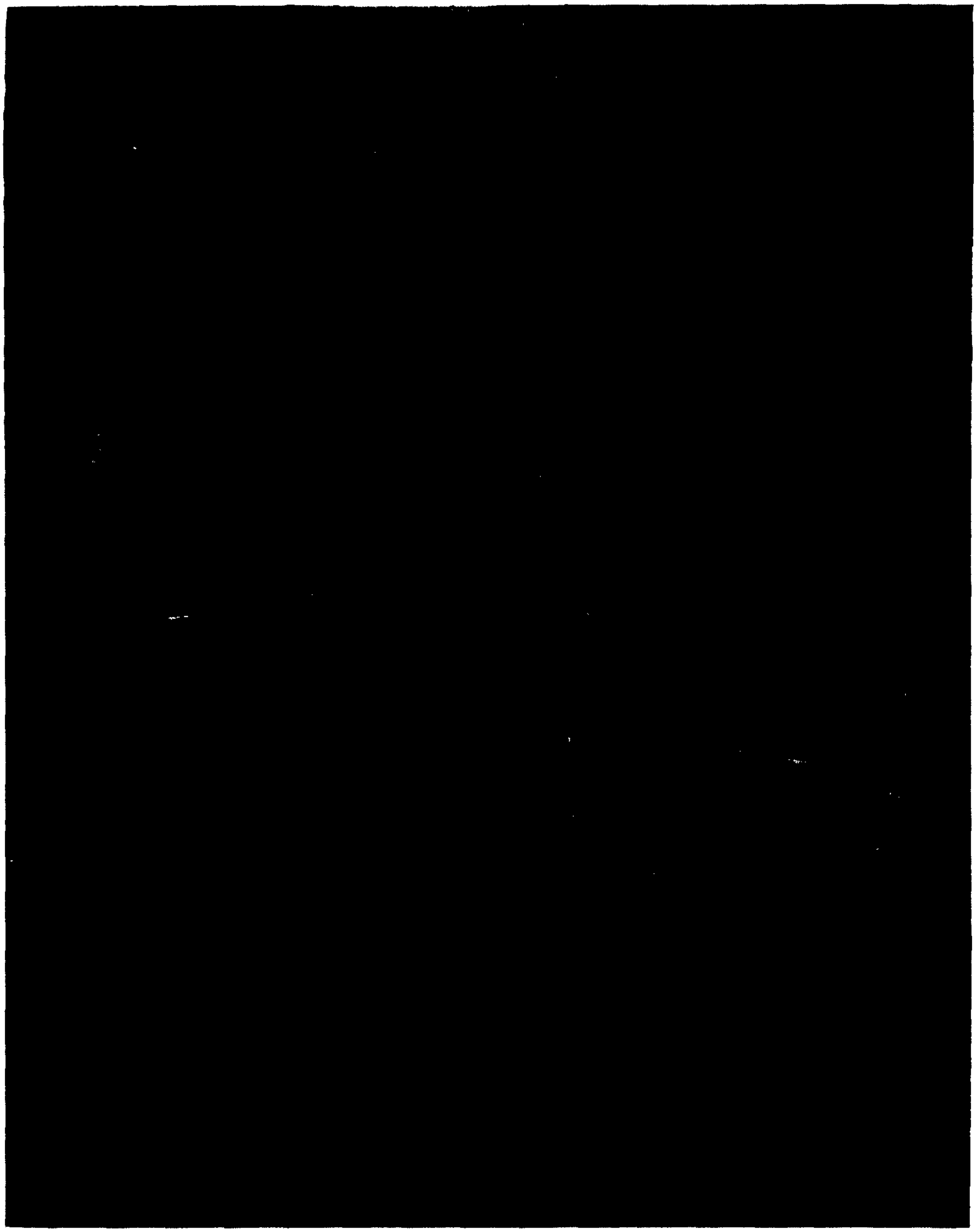
This stationary comb design was not suitable for headers since the leads were bent by or wrapped around the rigid danglers. A barrel with "button type" contactors was procured for plating headers. The advantages of this system is that it provides positive contact and does not interfere with the tumbling of the work in the rotating barrel. The system consists of a conducting shaft on the cylinder head joined to a spider of stainless steel embedded in the cylinder head which in turn is joined to embedded rails in each cylinder wall apex into which the exposed buttons are screwed. Due to the shape of a mass of headers, continual positive contact on each button was not possible. This affected the current density which resulted in poor plating. The buttons were removed and replaced with rods running the length of the cylinder. The contact improved but there was a tendency for the headers to enmesh forming a tangled mass. By compartmentalizing the barrel, tangling and bending of the leads was markedly decreased. Trial prove-in lots with the 2N559 header were plated with a 90 percent average yield. No sustained shop trial runs were made with 2N559 headers; however, a similar oval-type header with three 1-1/2 inch in-line leads was plated in lot sizes of 3000 with an overall yield of 90 percent.

IV Conclusion

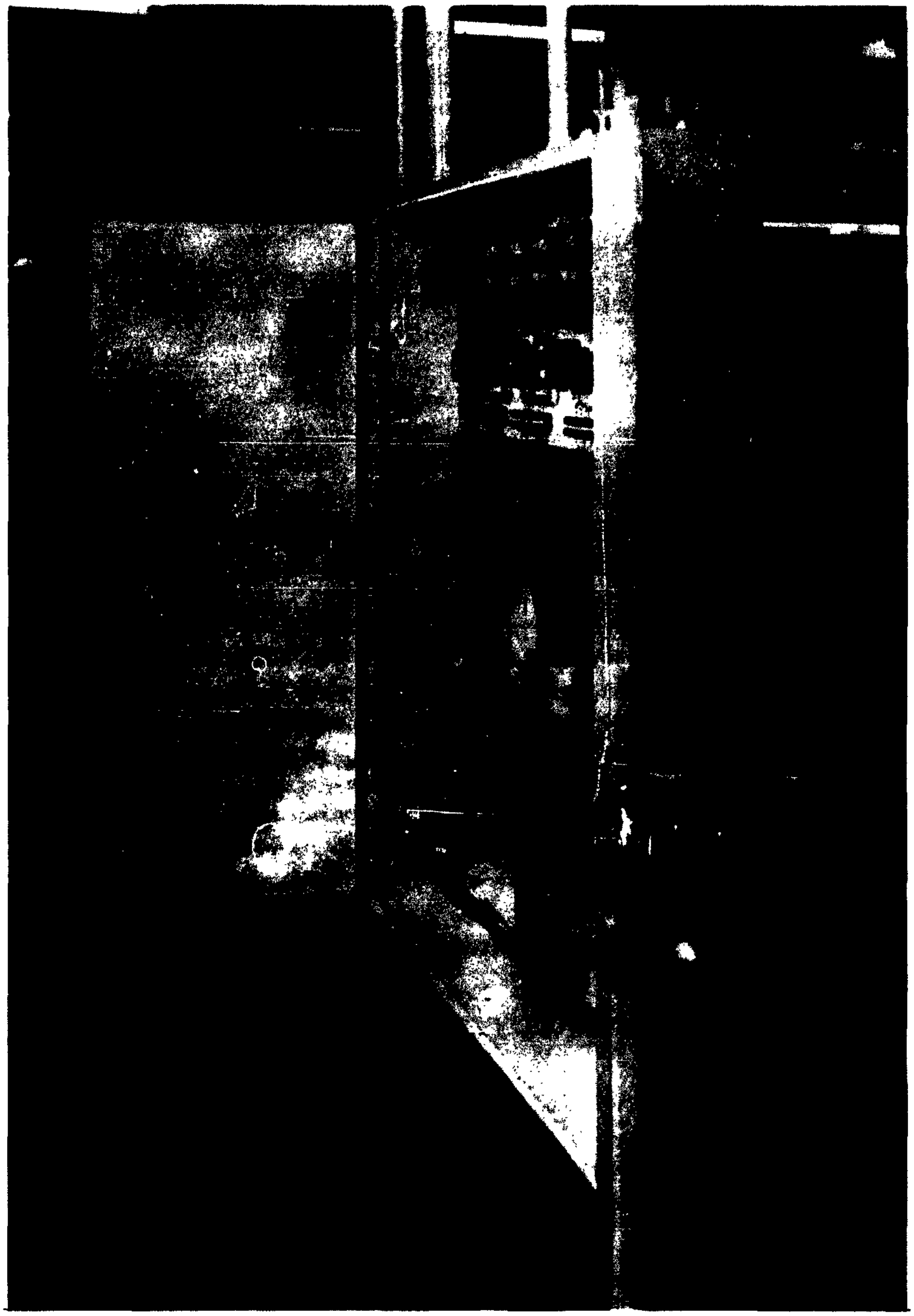
The overall objectives and design criteria established for mechanization of the cleaning and plating processes for tubulated cans and headers were met. Fundamentally this consisted of developing a general purpose plating machine capable of plating a variety of piece parts and then, if warranted, procure a specific purpose plating machine for the piece part in question.

The general purpose Automatic Barrel Plating Machine procured was capable of plating a variety of piece parts and possessed inherent flexibility for changing or modifying the cleaning and plating cycles. Barrels to plate the tubulated cans and headers were designed, developed, and proved-in. The Automatic Barrel Plating Machine coped with the anticipated changes in the cleaning and plating cycles, configurations of piece parts and amount of gold deposited. Tubulated cans in lots of 10,000 were plated with a greater than 99 percent yield. A smaller grained and denser gold plate was obtained. This coupled with the burnishing of the plate due to the tumbling action in the rotating barrel gave a gold plate with greater resistance to corrosion and greater resistance to absorbing contaminants.

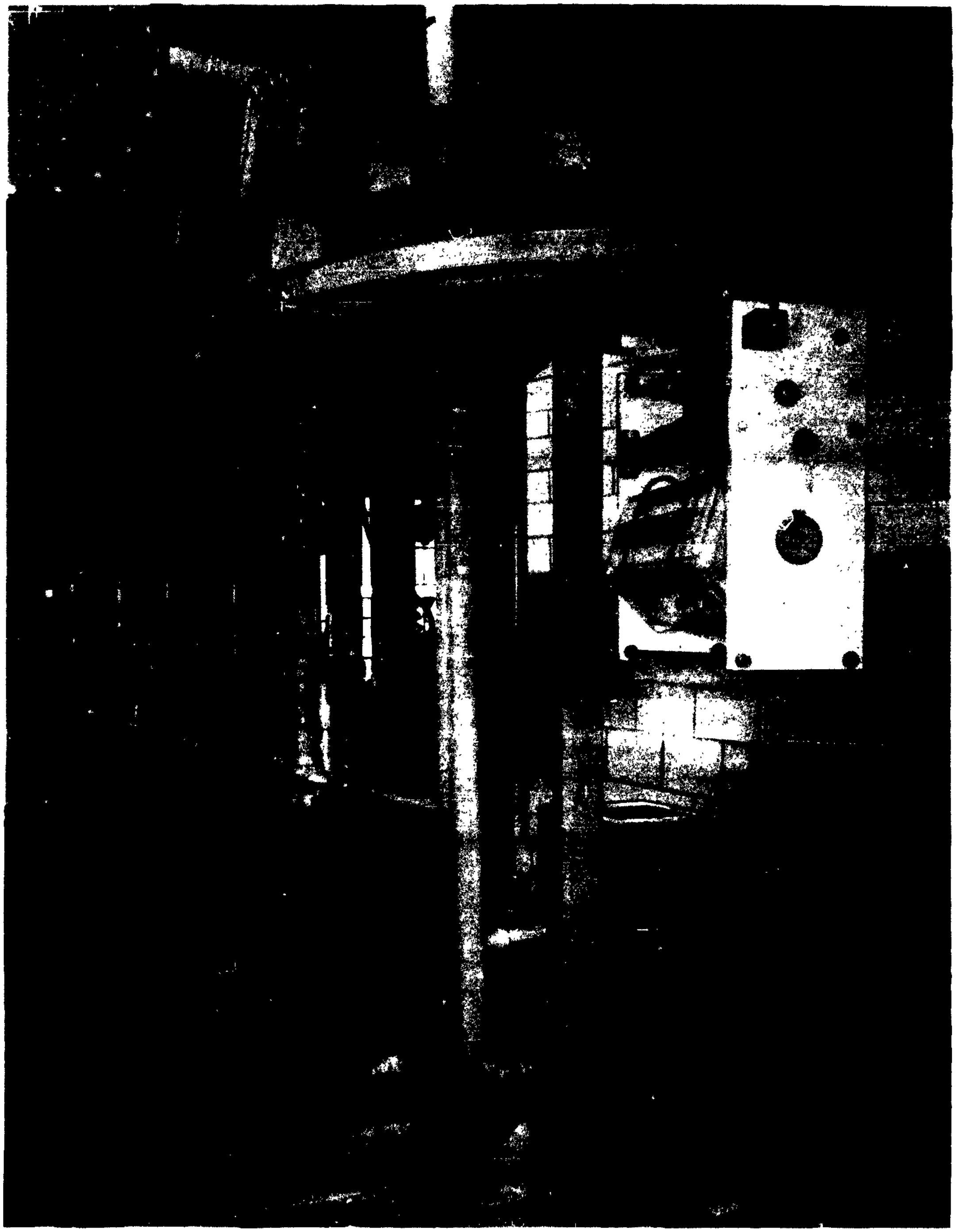
Headers were barrel plated in lots of 3,000 with a 90 percent yield. Later developments indicated that a special purpose machine was warranted; therefore, the Continuous Racks Plating Machine, Section 3.9, for header plating was undertaken.



AUTOMATIC BARREL PLATING MACHINE
FIGURE 3.3-1



MASTER CONTROL PANEL OF AUTOMATIC BARREL PLATING MACHINE
FIGURE 3.3-2



FREE WHEELING CARRIER OF AUTOMATIC BARREL PLATING MACHINE
FIGURE 3.3-3

AUTOMATIC BARREL PLATING MACHINE SHOWING DESCENDING CARRIER
FIGURE 3.3-4

RECTIFIER POWER SUPPLIES AND BATH TEMPERATURE CONTROLS
OF AUTOMATIC BARREL PLATING MACHINE
FIGURE 3.3-5

SECTION 3.4

PLATFORM LEAD WELDING

R. P. Loeper

F. J. Reinhard

PLATFORM LEAD WELDING

I General

The Platform Lead Welding Machine assembles a collector lead and platform by welding the two parts together at the rate of approximately 1,200 assemblies per hour. It produces subassemblies with accurately positioned leads perpendicular to the base of the platform. It is a 4-station semi-automatic machine with an independent fixture at each station. Accurate nest alignment of the parts before welding and uneven heat balance at the individual fixtures were the main problems encountered during prove-in. The machine is designed to permit complete interchangeability of all main components on the fixtures and for easy maintenance. If further development on this machine is desired, it will encompass automatic platform and lead loading, and possibly automatic collector lead subassembly unloading.

II Description of the Machine

This machine assembles a collector lead and platform by welding the lead within $\pm$ .005 inch of the nominal position and perpendicular to the platform within 2 degrees. The basic drive of the machine is a Ferguson Intermitter. This is a 4-station turret type indexing table of cast construction with a built in integral drive. Four completely independent fixtures which are positioned on the indexing table revolve about a stationary center column. Cams which control all fixture movements are mounted on this column. Directly above the cams is the stored energy power pack for the welding station.

Accurate alignment of the parts at the welding station is obtained by a die set type aligning fixture. The base of the aligning fixture has aligning pins which accurately guide the moving upper part of the fixture. The lower electrode is mounted in the center of a steel nest which locates the platform in the aligning fixture. The steel nest is mounted on a pair of thin steel cantilever springs which are deflected to provide the welding force and follow up needed after making the weld. This steel nest assembly is mounted on a cam operated cross-slide guided on the main base. This cross-slide, in the forward position, places a locating screw under the upper electrodes for positioning the lead wire with the proper lead length exposed. In this same forward position, the steel nest is also in position providing access for removing the welded subassembly and for loading another platform. At the welding station the cross-slide is in the retracted position free of the cam, and an adjustable stop accurately aligns the platform with the collector lead.

The top electrode is mounted on another slide which provides vertical travel. A partly slotted copper electrode is mounted on this vertical slide. The slotted part of the electrode is sprung open automatically, and a small cam lock forces it together. This cam permits the slot to assume three positions: fully open, lead load or semi-closed, and clamped. The cross-slide of the lower electrode, the cam lock for the upper electrodes, and the upper electrode height control, operate automatically as the fixtures revolve around the cams mounted on the stationary center column.

Three of the four stations require an operator at all times. At the first station a platform is hand loaded; at the second station a lead is hand loaded; the third station automatically welds the assembled lead and platform, and at the fourth station the welded unit is hand unloaded. Each index of the machine produces a completed unit. Since all manual operations are either loading or unloading, no special operator skills are required. During the regular work day the operators rotate positions periodically.

Normal maintenance consists mainly of replacing electrodes. The top electrodes are held in place by four flat head screws and the lower electrode is screwed into the bottom of the nest. If necessary, by removing five screws, a complete fixture including transformer can be removed in minutes allowing production to continue while the trouble is corrected. Figure 3.4-1 shows a complete fixture in detail and Figure 3.4-2 shows an overall view of the machine.

III Development

Originally, a completely automatic machine was considered for loading the lead and platform, welding, and placing the welded subassemblies into the ceramic molds prior to the Header Glassing operation. Some of the critical requirements of this welded subassembly were: weld strength, lead position, lead straightness and weld splatter. Weld strength was necessary to assure a good electrical connection and to afford the strength needed in later handling of the unit. Accurate lead position was required since it was one of the parameters of the finished transistor. Lead straightness was a requisite because it is essential to provide trouble-free operation of automatic machines used in subsequent operations. In keeping with good glass sealing practices the weld splatter had to be kept at an absolute minimum.

An experimental tool was developed to analyze methods to meet the requirements listed above. This research led to the development of a die set type fixture where alignment could be readily held between upper and lower electrodes. The upper electrode was developed as a split electrode with a small boss turned on the lower end. The boss solved the problem of gripping the lead as close to the end as possible and allows the electrode to enter the cup portion of the platform. Splitting the electrode and activating it with a cam arrangement as it rotated about the machine solved the requirement for an electrode that would be in the semi-closed position at the lead loading station, in the clamped position at the welding station, and in the fully open position at the unloading station. The experimental tool was used to develop a suitable weld schedule and to determine if the requirements for weld strength and position could be maintained.

Another experimental mechanism was also built to lift the welded subassemblies from the electrode nest and place them accurately into the ceramic glassing molds. This tool used a split finger with a small pin on each side of the split. The pins entered the holes in the platform and were then spread apart; in this way the subassembly was held firmly and oriented. When the subassembly was loaded into the ceramic mold, the pressure on the fingers was released allowing the collector lead assembly to remain in the ceramic mold as the transfer arm moved into position for another subassembly.

At this stage of development, time studies showed it feasible to construct the machine with four independent welding fixtures, and operate it manually while further development of the loading and unloading stations was undertaken. At this time it was also discovered that the subassembled units had to be decarburized before use in the next operation. As a result, a manually operated machine was built pending further development of the automatic aspects of the machine.

During the last stage of development, a fully automatic commercial machine became available which fulfilled our requirements. Since this machine was not a prototype, it was more economical to purchase than to develop our own. Under these circumstances further development of our automatic platform and lead loaders was no longer justified and development was stopped.

IV Operational Problems

During prove-in of the machine, problems concerning indexing, nest alignment, welding heat balancing, and welded subassembly removal were experienced. Indexing problems were centered around the drive mechanism of the machine. Since this was a standard drive furnished with the Ferguson Intermitter, some of the troubles experienced were quite unexpected. A complete clutch and brake unit was replaced before it was discovered that misalignment of the shaft of the indexing motor and the main drive shaft caused excessive heating, resulting in bearing wear and abnormal wear to the faces of the clutch and brake. After aligning the motor properly and installing a new clutch and brake assembly, this problem was eliminated. Next, the machine started to index in an erratic manner. This trouble was traced to the clutch which was originally designed to disengage electromagnetically during the dwell phase of the index cycle; however, even with the clutch disengaged electromagnetically the armature was so heavy that it stayed in contact with the field facing during dwell, causing excessive wear of the clutch armature and field magnet facing. To correct this condition, the clutch was modified by adding small springs to lift the clutch armature while it was disengaged electromagnetically. The cam which controls the clutch and brake activation was also modified to obtain better results. Further troubles in indexing were caused by failure of the timer supplied by Ferguson. A better grade timer was substituted but has not proven completely satisfactory. It was decided to completely rebuild the timing circuit. Material is on order to effect this change.

Nest alignment problems became apparent during prove-in. Back to front orientation could readily be aligned by adjusting a stop screw built into the station slide. The right to left orientation, however, was a bit more complicated. The springs on which the nests were mounted had to be loosened to reposition the nests, and in the process the back to front orientation was disturbed making accurate alignment extremely difficult. A cross-slide with an adjusting screw was substituted for the solid mounting blocks supporting the nest springs. Fine adjustment is now possible in both the back and forth and the right and left directions and simplifies nest alignment problems.

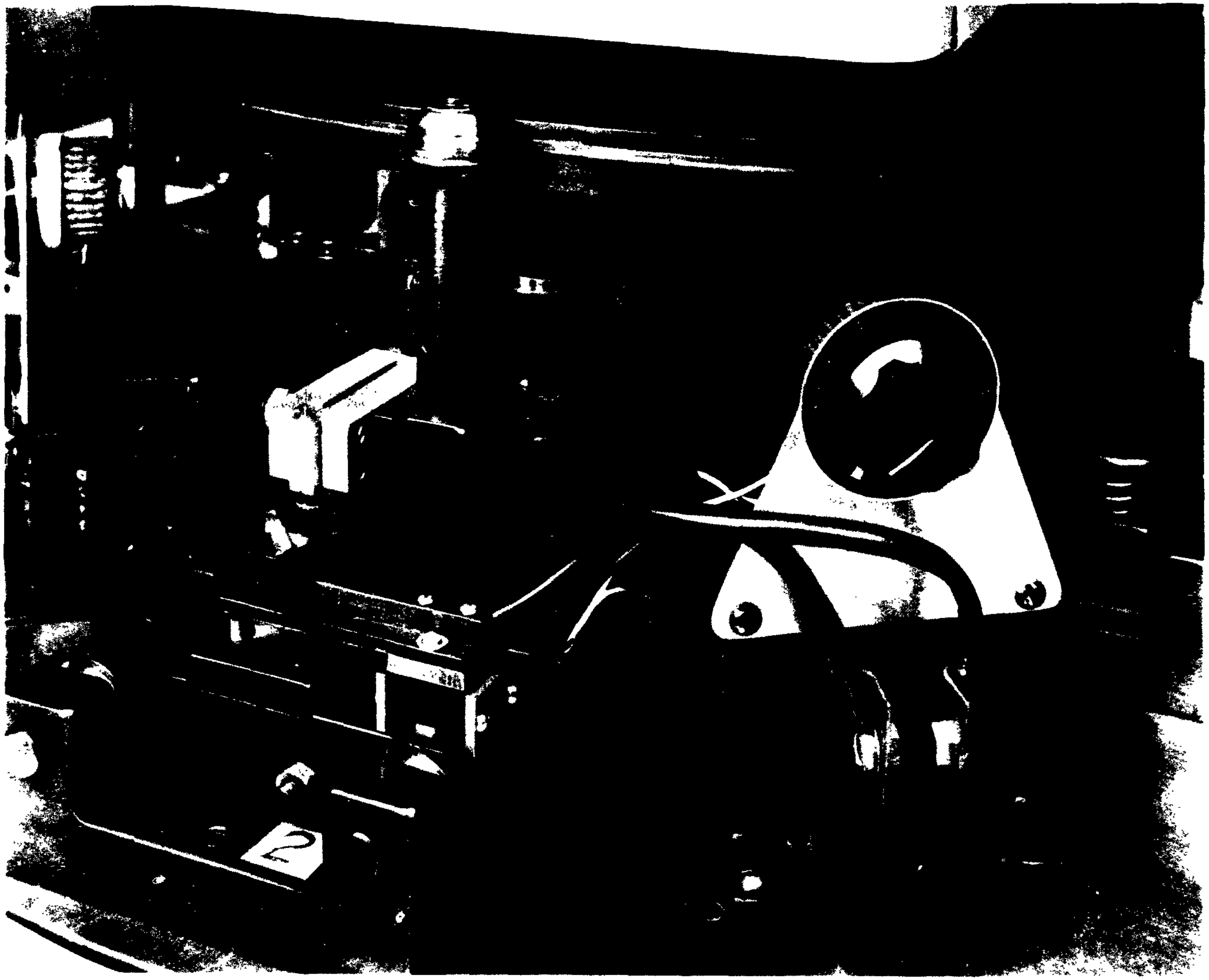
A heat balancing problem, or obtaining equal welding heat on each of the four fixtures from the same power supply, was solved by placing a rheostat, to vary resistance, on the primary side of the individual welding transformers. In this way, the welding heat was balanced and uniform welds were obtained.

Removal of the welded subassemblies normally is a quick hand operation; caution must be used, however, to keep from disturbing the perpendicularity of the welded collector lead. Occasionally, subassembled units stuck to the bottom electrode with the result that they were difficult to remove. Since the dwell time is less than 2 seconds, the machine had to be stopped resulting in production interruption. Also, many of the collector lead subassemblies were usually bent or damaged in the process of removing them. The nest holding the platform was redesigned and an ejector type nest was developed. The operator had to squeeze two levers to eject the subassembled unit. Four nests were built and tried in production. It was discovered that in actual operation, the operator had the tendency to occasionally twist the cantilevered springs which support the nest, with the result that the accurate lead positioning was continually being disturbed. The nests were again redesigned. Opposite sides of the nest were recessed and a tool then fitted into the recess to free the stuck subassemblies with a prying action. This method proved successful and is the one now in use.

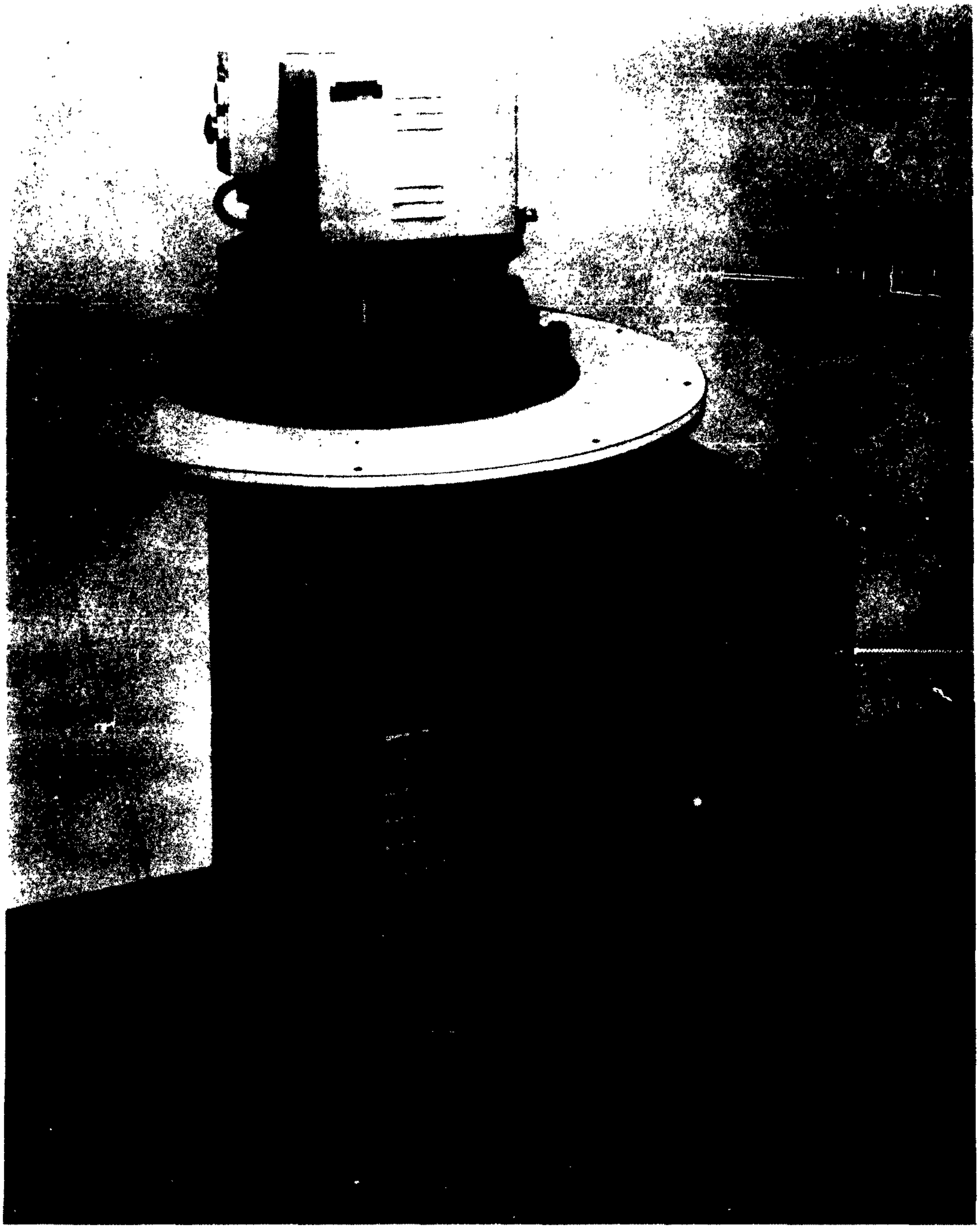
V Conclusion

The development and design of the Platform Lead Welding Machine provided butt welded subassemblies with collector lead accurately positioned in the platform. At present the machine is operating on a 2-shift, 6-day week basis and has reached our estimated net hourly output of 1,200 platform collector lead assemblies per hour. The requirements of the product have been met.

With an automatic Platform Collector Lead Welder available on the commercial market, it is no longer economically feasible for us to design and build automatic loading and unloading stations for this machine.



WELDING FIXTURE AND HEAT CONTROL OF PLATFORM
LEAD WELDING MACHINE
FIGURE 3.4-1



PLATFORM LEAD WELDING MACHINE
FIGURE 3.4-2

SECTION 3.5

HEADER ASSEMBLING

R. P. Loeper

J. P. Reber

HEADER ASSEMBLING

I General

Piece part assembly of TO-18 headers is completed on a straight line Header Assembling Machine. The machine receives ceramic molds filled with manually loaded collector lead-platform subassemblies. As these molds are indexed along a track, it successively adds two leads, a glass ring and a glass slug to every subassembly. Finally, it forms and welds the three lead ends together with a gross output of 1800 headers per hour preserving lead straightness and cleanliness of the component parts. Figure 3.5-1 shows a ceramic mold with a collector lead sub-assembly and progressive additions of component parts including a header after the Glassing operation.

The machine replaces a manual process which required the combined services of many people. The most difficult problems encountered during the project were the feeding of leads and glass reliably. The machine has undergone many changes from the original design. Developments resulting in advances in the state-of-the-art caused many of the changes. Further, improvement of the machine would result from the development of a mechanical means to load collector lead-platform subassemblies, and a means to insure the cleanliness of the molds since one of the greatest causes of machine malfunction has been the rapid buildup of oxide in the mold cavities, particularly the lead wire holes.

II Description

The machine is rectangular, and built on a box-type frame. It is 8 feet long, 2.5 feet wide and 2.5 feet from the floor to the table top upon which all stations are mounted. Figure 3.5-2 shows an overall view of the machine. It has a feed track with a ratchet type indexing pawl bar running near the front edge or operator's side. Glassing molds, filled with collector lead-platform subassemblies, are fed into the indexing mechanism from a magazine extending toward the back along the left side. As the molds are moved along the track, the second station adds two leads to each subassembly. Figure 3.5-3 shows a close-up of this station with the glass feeding stations and tip welding station to the right.

These leads are fed one from each of two hoppers which hold them in a horizontal position. They are discharged from the hoppers by falling into slots, made to hold only one lead, in reciprocating circular segments which form the bottoms of each hopper. At the proper time, during the reciprocating motion, they are ejected from the slots into chutes that turn them to a vertical position and guide them into an inserting mechanism. The inserting mechanism aligns the leads with the mold cavities and seats them with a sliding frictional force.

The third station adds a glass ring to each subassembly. A vibratory feeder is used to orient and feed the glass rings into a track from which they are released, one at a time, by a cam operated mechanism that gathers the leads and drops the ring over them. A glass slug is added at the fourth station. Here again, vibratory feeding is used to orient the slugs and feed them to an escapement. After being released from the escapement, a slug is dropped onto a chute and propelled by gravity over the mold feed track to another chute that changes its direction and guides it into position in the mold.

At the fifth station the lead tips are formed and welded together. A completely cam controlled mechanism is used here to comb, clamp, form and make the weld. A cam propelled push bar is used at the last station, the unload station, to remove the molds from the feed track and push them toward the back of the machine where they are stored prior to future processing.

All stations except the first, which is motivated by a weighted bar, are driven from one main shaft running lengthwise below the table top near the front. The main shaft is powered by a variable speed drive unit consisting of 1/2-horsepower motor and a belt driven reductor. The reductor drives the shaft through a pair of gears. The pawl bar of the indexing mechanism is controlled by a shifting cam on the main shaft; the index is performed during the spring driven portion of the stroke, as this provides a safety in the event of interference with the molds. The lead and glass ring feeding stations are rendered inoperative when a mold is not in position to receive parts by solenoid operated clutches on the drive shaft. These solenoids are controlled by mold actuated switches located in the feed track. The glass slug feeder escapement is also solenoid operated; however, here two series connected switches are used for control. One switch is mounted in the track and operates in the same manner as the clutch switches previously described; the other switch is pulsed by a cam on the main shaft and is used to energize the solenoid at the proper time.

The welding station is in motion continuously while the machine is running, but the electrodes are so spaced that there is no passage of current unless leads are between them. The cam propelled bar used to push the molds from the feed track is actuated when molds are indexed against a switch located at the end of the feed track. The switch energizes a solenoid releasing a single revolution clutch that turns the cam. Pulsed compressed air is used at three places on the machine:

in the inserting mechanism of the lead feeder to clear it of improperly seated leads; on the supply track of the glass ring feeder to keep the escapement filled; and across the top of the molds between the glass slug and welding stations to clear away any glass not in its proper place. The air is supplied by a compressor mounted within the machine; pulsing is obtained from a cam mounted on the main shaft that trips a switch to energize a solenoid operated valve.

Electrically the machine is a self contained unit requiring only a connection to a 440-volt, 3-phase, 60-cycle, 2-KVA source. All transformation to 110 volt A-C single phase, 24 volt A-C and rectification for 24 volt D-C is done within the machine. The main drive motor is powered by 3 phase, 440 volt A-C. 110 volt A-C is used for lighting, welding, pumping air and vibratory feeding. Rectification for the 24 volt D-C control circuit is provided by a full wave rectifier made of four silicon diodes. 24 volt D-C power is used because it is a safe low voltage and operates solenoids more quietly.

The duties of the operator, while the machine is running, consist of keeping the various hoppers filled, clearing or preventing jams by prescribed methods and the replacing of parts that may have been missed at the various stations.

In order to keep the machine operating properly, certain preventive maintenance measures must be taken. In addition to regular lubrication, the electrodes should be checked and dressed if necessary; also, the condition of the lead formers (benders) should be checked and corrected. These checks should be made at least once in every 24 hours of operation. Checking of the lead formers is manditory after a jam occurs that warrants stopping the machine to clear the jam.

III Development

Feasibility studies conducted on Header Assembling centered mostly around methods of feeding leads and glass. There was never any question about the need for a mechanical means of assembling headers, because of the high volume requirements for the anticipated Nike Zeus production. A manual assembly method simply could not meet the demands of such a project.

Feeding wires .017 inch in diameter and 3 inches long from a bundle with any degree of regularity is one problem, but when those wires are dead soft and have an oxidized coating which may not be disturbed, separation from a bundle and their insertion into a mold becomes a complex problem.

The first method of feeding leads utilized a reciprocating lineal motion which moved a bar containing a slot across the exposed face of a spring loaded bundle of leads. This idea was abandoned after trial because the oxidizing process stress relieved and warped the leads to such an extent that they could not be picked off without disturbing the oxide coating if picked off at all. The back and forth motion of the bar containing the slot also caused oxide to flake off those leads still in the hopper.

A rotating slotted drum was then developed in an effort to cut down the jostling of the leads in the hoppers. A station was built using this method of pick-off. It had three hoppers in which the leads were held upright and forced against the drum by a weighted back plate. The leads were dropped into an intermediate stage containing carriers which received one lead from each hopper and at the proper time dropped them into a third stage which inserted them into glassing molds as they were indexed through the station. This station was used on the machine for a long time; it reduced the amount of flaking of oxide from the leads in the hoppers and was more compact than one using the reciprocating lineal motion bar type, but location of components and the timing of the stages had to be very precise. This precision was never maintained to our satisfaction. However, the method and mechanisms used on this station were deemed so unique that a patent covering them has been applied for. Meanwhile, the state-of-the-art in header design and manufacture had been advanced by two developments: Processes were developed to oxidize metallic parts after header assembly and to butt weld collector leads to the platforms before header assembly. These changes, along with a reduction of the lead length, greatly simplified the problems of feeding leads and inserting them into molds on this machine. The present station was designed as a result of this simplification.

Before glass feeding by the present method was chosen, a number of methods were investigated. One method was to fill the platform with a measured amount of glass in bead form. The beads were large enough so they would not pass between the lead and the clearance hole in the platform, yet small enough so a goodly number were used. This method did not prove successful. Test results showed that the molten glass flowed unevenly resulting in unequal distribution usually with a large meniscus formed around one or two of the leads and, in many instances, glass ran over the edge of the platform. Substitution of a single glass bead, of the correct volume, was then tried. This method also produced unequal glass distribution but not as many instances of glass running over the edge of the platform. Glass preforms available during the development period of this machine did not produce the required clear glass seal so they were not usable. Preforms available now, although improved, still do not meet all of our requirements. Therefore, in order to obtain more uniform glass distribution, it was decided to provide the glass in ring and slug form. The glass ring feeding station has never been changed from its original design, with the exception of lowering the escapement to accommodate headers with shorter leads.

The glass slug feeder has been rebuilt twice. The original design used a bushing, with a reciprocating vertical motion applied to it, submerged in a hopper to fill a tube with the slugs. At the proper time the amplitude of the pulsation was made large enough to push a bar, by cam action, and force the bottom glass slug ahead into a feed track. With the feed track filled with slugs, this pushing action forced the slug at the outer end of the track to drop off into an awaiting mold. This method worked until the advent of the header with the butt-welded collector lead design. The new header design required a 90 degree rotation of the leads in the glassing mold, positioning two of the lead wires so that the glass slug had to be forced between the leads to load it properly. The original lead arrangement presented no problem for only a single lead wire had to be passed and this was easily done.

The original slug feeder was not capable of consistently performing the operation due to an accumulation of tolerances of the slug diameter that caused uneven spacing in the feed track. To overcome this problem, it was decided to push one slug at a time from the bottom of the feed tube out through the feed track to a point between the lead wires where it could drop into the platform. Three problems, which could not be overcome to our satisfaction, forced the abandonment of this new method: Keeping the glass slug upright was one of them. Constrictive resilient materials were placed in the feed track to keep the glass slug upright; however, they did not last long enough to be economical. Preventing the slug from being propelled over the mold cavity as it passed between the lead wires was another problem; even after the station was raised to allow the slug to be pushed between the lead wires at a point where less spring action from the wires was encountered, control of the slug could not be maintained. The butt welded collector lead presented the third problem. When a lead had not been welded in its proper position or had been bent by handling so that it prevented the glass ring from dropping into its proper position, the glass ring was shattered when the glass slug was pushed into the mold. This resulted in fouling of many molds because the glass chips which were not removed fused to the mold in the furnace during the Header Glassing operation. Glassing molds fouled in this manner could no longer be used because they caused malfunctions at the various stations on the machine and the fused glass could not be removed without intolerable damage. The present glass slug feeding station, described previously in this report, does not feed slugs between the leads and is not obstructed by improperly seated glass rings.

The lead tip welding operation was not a part of Header Assembling at the inception of this project. During the development of mechanized processes for high volume transistor production, preservation of lead straightness was found to be advantageous. The original design of this machine was almost completed when welding the lead tips was conceived to strengthen the leads and preserve lead straightness. A welding station was then added. The first trial at preserving lead straightness was to randomly gather the leads, near their tips, and weld them together. This method was not reliable. Electrical resistance of the oxide coating on the leads was too high to obtain a weld strong enough to withstand the heat of the glassing furnace as well as the stresses applied while barrel plating the headers. In an effort to keep the lead tips unoxidized for ease of welding, resistance heating of the portion of the lead used in the glass seal was then tried. This heating was done in the proper atmosphere in order to form a good oxide coating. The oxide formation was good; however, the method had to be discarded as the resistance heating caused strains and deformations of the lead that could not be tolerated. It was not until after the development of the process whereby the oxide coating was applied to the various parts after they had been assembled in molds that a satisfactory lead tip weld could be made.

A plating problem arising from randomly gathering the leads and making the weld, unforeseen when that method was chosen, forced further refinement of the welding station. An undesirable condition known as "shadowing" arose. This was caused by the proximity of the leads as welded which prevented proper flow of the plating ions and resulted in uneven plating. To overcome the problem, three things were done: the leads had to be combed; the two outer leads had to be formed in toward the center one, and the three lead tips had to be held in one plane and then welded together.

The glassing molds originally designed for use on the machine had 13 positions and were made of inconel. Inconel was chosen because it had a greater wear resistance than carbon and withstood the high temperature in the glassing furnace better. Two cylindrical pieces, machined and then pressed together, formed one subassembly or individual mold position. Thirteen of these subassemblies were then aligned and pressed into one rectangular bar 5 inches long to form what is called a mold. They were difficult to make and expensive. Much time was spent on liaison between the suppliers and Western Electric Company personnel in development of manufacturing methods during the procurement of them. Change-over to ceramic glassing molds was done for two reasons: First, because ceramic molds are easier to make and cheaper. Secondly, inconel could not be used with the new glassing process since the oxide coating is applied to the leads and platforms after they have been assembled in the molds. Oxide build up on inconel was too rapid.

The ceramic molds are also rectangular but have only 12 positions in a 5-inch length. The number of positions was reduced to provide more clearance between units. These molds are molded to rough dimensions, heat treated, then machined to final dimensions and finally fired. The change-over to ceramic molds caused changes to the indexing pawls and the mold locators. On the inconel molds all indexing and locating was done using the cylindrical portions that projected above the rectangular base piece. The ceramic molds have no projections, instead notches in one side have been provided for indexing and locating. The index pawls that were used for the inconel molds were reshaped and relocated to suit the ceramic molds. These did not provide the precision required. The pawls had a tendency to slip out and move the mold ahead in an unpredictable manner. Both the pawls and the mold notches were redesigned and have worked trouble-free since.

The machine, as originally designed, had a station to unload molds as they returned from the furnace. It also had a station for loading platforms. Both these stations were rendered obsolete with the advent of the collector lead-platform subassembly. These stations have been removed. There were also a series of fault detectors, located at various stations. These were found to be troublesome and superfluous; they were also removed.

The drawings for the original machine were made at the Reading, Pennsylvania office of Sanders and Thomas, Inc., Pottstown, Pennsylvania. This was done under daily supervision by Western Electric Company personnel.

The machine, except for the frame, was constructed at the Laureldale Plant of the Western Electric Company, Inc. The frame was built by the Textile Machine Works of Wyomissing, Pennsylvania.

IV Performance

The shop trial runs of the rebuilt machine were started in September 1962 and completed by the end of December 1962. During that time over a half million headers were assembled with a mechanical yield of 90 percent. Inspection records taken from random lots of headers after glassing permitted the categorizing of defects. The information gleaned from these sample lots was then used to determine probable causes of improper machine performance. A portion of the sample had bad lead location: Improperly welded platform-lead subassemblies that cannot be securely held during the tip welding operation are the greatest cause of this defect. Oxide build up in the molds also caused trouble; on oxidized molds, the leads were much harder to insert causing jams at the lead feeder. Many of the headers in these molds would also stick in the mold cavity. This condition causes cracked glass at the meniscus around the leads due to the excessive force needed to pull headers out of the mold cavities.

The glass feeders in general worked very well during the shop trial runs. Troubles encountered were caused by an occasional broken or out-of-specification piece of glass. These malfunctions caused headers to be assembled without one of the pieces of glass until the defect was observed. Missing pieces of glass could be added by hand before the parts were admitted to the glassing furnace; however, occasionally a header slipped by without this correction and had to be rejected for low glass. Mechanical sorting of the glass will be investigated in an effort to cull out defective glass parts.

Bent leads, both on platform-lead subassembly and the two isolated leads, gave trouble on occasions. Bent isolated leads affect the working of the lead feeder while bent collector leads on platform-lead subassemblies interfere with smooth operation of the tip welding station. Malfunctions caused by bent leads disturb the fine adjustments necessary on the lead feeding and tip weld stations.

In general performance during the shop trial was satisfactory. The two main offenders were the faulty parts (bent leads, broken or oversize glass, and improperly welded platform-lead subassemblies) and the difficulty encountered in keeping some of the mechanisms in the close adjustment necessary for continuous operation.

V Evaluation

The addition of this machine to the facilities for TO-18 package transistor production makes possible a greater output of a more uniform product than the manual method. One machine operator with two helpers to load collector lead-platform subassemblies, can process 1,440 units net per hour. Using manual methods, one person is pressed hard to maintain an average hourly output of 200 assemblies and those units would still require lead tip forming and welding; another person would be required to do that. The average hourly output of a manual straightening, tip forming and welding operation is only 300 units net per operator.

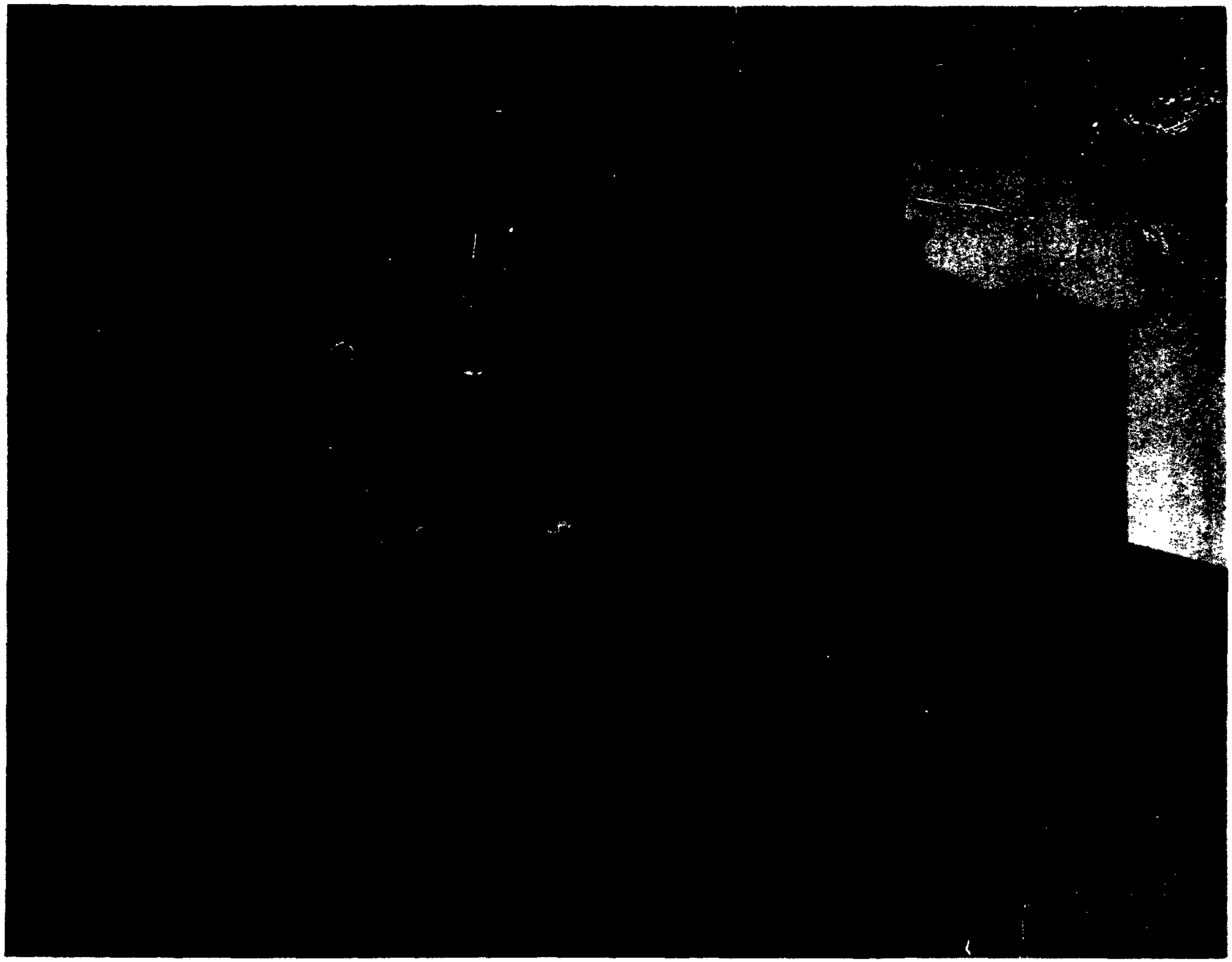
Although this machine does save a great amount of floor space and does produce a more uniform product at a higher rate per operator; improvements could be made that would increase the output per operator. One improvement would be the addition of a station to mechanically load the collector lead-platform subassemblies. This would release the two persons now performing that task. Another improvement, perhaps needed even more than a subassembly loading station, is the development and application of a method to insure the cleanliness of the molds used on this machine.

This machine will do all that it was designed to do. Its efficiency is dependent on the quality of the materials handled by it.

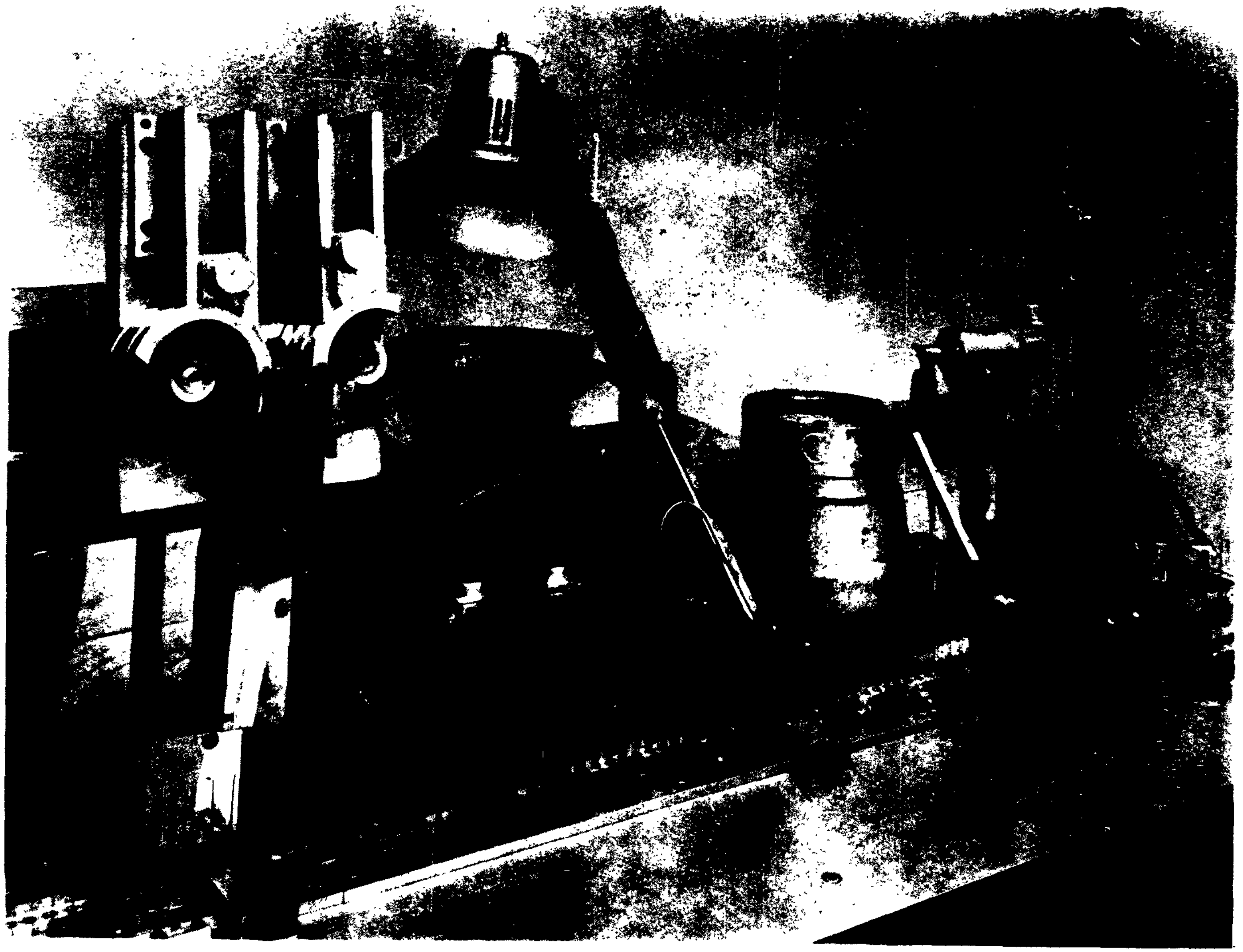
VI Conclusion

The machine fulfills the purpose of providing a means for the high volume assembly of TO-18 headers. It does this even though the product and processes have been changed numerous times. Some of those process changes were brought about by problems encountered during the prove-in of this machine. However, improvements such as those previously described should be made during Phase 2 to increase its output.

GLASSING MOLD SHOWING PROGRESSIVE HEADER ASSEMBLING
FIGURE 3.5-1



TO-18 HEADER ASSEMBLING MACHINE
FIGURE 3.5-2



ASSEMBLY STATIONS OF HEADER ASSEMBLING MACHINE
FIGURE 3.5-3

SECTION 3.6

HEADER GLASSING

L. R. Sell

HEADER GLASSING

I General

The Header Glassing Machine, or Seal-Ox Furnace, is a dual atmosphere furnace which oxidizes metal piece parts in one zone and fuses a glass-to-metal seal in the second zone. The unit, or header, is preassembled before entering the furnace.

The objective of this equipment is to produce a hermetic glass-metal seal with sufficient mechanical strength to withstand subsequent thermal and mechanical shocks induced during the wafer bonding, wire bonding, and encapsulation operations. Greatly contributing toward this objective is the unique processing feature of this furnace which allows the forming of an oxide at 800°C and the glassing at approximately 980°C without cooling the oxide to ambient between these two operations. Since the induced oxide has a very slightly different coefficient of expansion than the parent metal, it can be recognized that there exists a tendency for the oxide to flake off unless many prerequisite conditions exist. This new process, therefore, circumvents many of the conditions which may cause flaking by accomplishing the seal before the oxide cools.

In addition to consolidating many furnace operations into one, the furnace is capable of glassing approximately 3,200 TO-18 headers per hour or 1,600 TO-5 headers per hour. This is an increased production rate of at least 50 percent over any pusher furnace now in operation at Laureldale. By virtue of the fact that all oxidizing of metal parts is done after parts are assembled, the need to handle oxidized metal parts in mechanized operations prior to glassing is eliminated. This eliminates all possibilities of oxide deterioriation or contamination due to handling or assembly operations.

Output of the furnace after several months has been at the design level for both TO-5 and TO-18 headers. The furnace has not been turned off due to technical difficulty since prove-in was completed. The only down time accrued by the furnace was due to periodic cleaning and temperature probes. No further modifications are anticipated on the furnace proper.

II Unmechanized Process

The present manual process utilizes four furnaces: two furnaces for lead preparation, one dual-purpose furnace for platform preparation, and one furnace for header glassing. The manually made header is processed as listed below:

1. Leads Preparation
   a. Chemically cleaned
   b. Pre-oxidized in conveyor furnace
   c. Chemically recleaned
   d. Decarburized in pusher furnace
   e. Oxidized in conveyor furnace
2. Platform preparation
   a. Chemically cleaned
   b. Decarburized and oxidized in Tandem conveyor furnace
3. Assembly and Glassing
   a. Assemble glass and metal
   b. Fuse glass at 1000°C in glassing furnace with slightly oxidizing atmosphere

The present glassing furnaces have an hourly output of approximately 2,000 TO-18 headers per hour.

III Description of Furnace

The furnace is 36 feet long, 6 feet high and 2 feet wide (see Figure 3.6-1). A one-piece inconel muffle of "D" type construction is supported on a structural steel frame and suitably insulated at all high temperature areas. Nitrogen and air are piped beneath the muffle and are introduced into the muffle thru holes in the muffle floor. Atmosphere is extracted at the entrance and exit of the oxidizing zone by means of a BTU Engineering Corporation patented diaphram. Basically the diaphram consists of an annular shaped piece of tubing containing a number of holes thru which the atmosphere is drawn. Provisions are made around this ring for cooling due to the high temperature of the gas being extracted.

Boats are automatically loaded by means of a pneumatically operated rod which pushes boats off a feed conveyor onto the furnace conveyor. A pair of photoelectric interlocks and a timer regulate the rate of boat feed and prevent jam-ups. The timer setting determines the space allowed between each boat.

The instruments and flow rates are grouped in one panel located directly above the glassing zone. (See Figure 3.6-2.) The entire panel can be removed from the furnace by removing the bolts at each corner support, disconnecting all atmosphere lines, and disconnecting the 440 volt power line.

The exit end of the furnace contains a 3-foot water jacket which is attached to the muffle with a bolted flange. The water jacket requires very little water flow (less than one gallon an hour).

The furnace is zoned into essentially four parts: the first, or preheat zone, raises the temperature of the header to 800°C in a nitrogen atmosphere. The second zone is the oxidizing zone (800°C) and contains dry air. The third zone is the glassing zone (1,000°C) and contains nitrogen. The last or cooling zone, contains nitrogen and anneals the glass seal while bringing it down to room temperature.

The furnace is separated electrically into four zones. The first zone is heated by an 18-inch set of elements regulated by a Brown Pyrovolt Controller.

The second zone consists of 4 sets of elements, each 12 inches long, controlled by 2 Brown Pyrovolt Controllers (two sets of elements per controller).

The third zone consists of two 18-inch zones and two 12-inch zones. Each of the two 18-inch elements are controlled by an individual Pyrovolt Controller and the two 12-inch elements are controlled by a single Pyrovolt Controller.

The last zone consists of four sets of elements, all controlled by a single "Pyr-O-Vane" Controller.

Power to the elements is regulated by individual Power-Props. The Power-Prop is a piloted control capable of controlling power to a non-inductive load in response to a proportional D-C signal. The major element consists of two silicon controlled rectifiers which will pass zero to full load power, regulated by a D-C signal. The Power-Prop can shut the load power off completely, load power being proportioned down to about one percent of maximum load, and ON-OFF below that point.

The furnace is protected against overheat by four Weston Sensitrol Overheat controls. Two controls are preset for the oxidizing zone and two for the glassing zone. Power to the entire furnace is shut off if one of the Overheat switches is actuated.

Maintenance consists essentially of lubricating all belt pulleys and the periodic calibration of controllers and recorder. Normally the muffle can be expected to be replaced every two years.

Operation of the furnace by an operator consists only of loading boat loads of glassing molds on the feed conveyor and removing finished product at the exit end of the furnace.

IV Machine Development

Experimental oxidizing and glassing tests were first run in an existing conveyor furnace which was manually controlled. When these tests proved the oxidizing and glassing cycle feasible, a set of specifications involving temperature contours, atmosphere control, and belt speed was assembled. These specifications were submitted to BTU Engineering Corporation in Waltham, Mass. BTU Engineering Corporation then designed and constructed the entire furnace around these specifications. No unusual design or construction problems were reported by BTU.

V Operational Problems

During prove-in the Zone 1 Stepless Power supply was found to be faulty. A new unit was installed to rectify the situation.

The initial experimental runs were made with compressed air circulating thru the diaphrams at both ends of the oxidizing zone. The air was supposed to induce an exhaust of atmosphere gases due to the forced convection principle. Very little atmosphere was exhausted with this arrangement. Water was then circulated thru the diaphrams in an attempt to create a greater temperature differential and thus induce more exhaust. This attempt was also unsuccessful. Two Fisher vacuum pumps (Cat. No. 1-094) were purchased and connected to the diaphram outlets in addition to a flow rate for each line. These pumps produced the desired exhaust and have been in operation over eight months.

VI Shop Trial

Before Shop trial began a change was made in header design for all TO-5 and TO-18 headers. It consisted of butt welding the grounded lead to the platform before glassing. This welding operation before glassing appears to contaminate the rodar platform so that a decarburizing operation is necessary to clean the platform-lead subassembly before processing thru the Seal-Ox furnace. However, this cleaning operation seems to leave the metal surface in a good oxidizable state for a relatively short period of time; i. e. less than one day. (This means that the process must be speeded up to a point whereby parts are decarburized, assembled, and sealed within a short period of time.)

Defects due to a long delay show up as large numbers of small bubbles on the platform sidewall. In extreme cases the bubbles are large enough to cause rejection of headers. In most instances the bubbles are small enough so that an acceptable unit is produced, but the very presence of these bubbles indicates that more work must be done in the pre-furnace operations to eliminate this bubble problem. Bubbles have been one of the major defects, attributable to the furnace, in units produced throughout the pilot run.

Another fact noted during the shop trial run is that at the beginning and end of each run the furnace is not completely stabilized, thermally or atmospherically. This unstable condition results in lead fatigue defects and a heavy oxide coating on leads and platform. To compensate for this a number of dummy boats loaded with ceramic blocks are run before and after each run of headers. These blocks tend to stabilize the entire furnace and eliminate the aforementioned problems.

A single furnace setting for both TO-5 and TO-18 headers has been the objective during both the trial period and the pilot run. However, except in isolated instances, a trend has developed which shows the oxide on TO-5 units is less than TO-18 under identical conditions. Many furnace settings were tried to develop a compatible set of conditions but none have been successful for a prolonged period of time. Tests are still being conducted in this area.

VII Furnace Performance

Output has been at the predicted rate but variations in quality due to the short processing time available and incompatibility between TO-5 and TO-18 has caused the yield to be lower than predicted. During the pilot run period manually glassed units have run at approximately 10 percent higher yield than the Seal-Ox processed units. Major causes of Seal-Ox rejects, attributable to the furnace only, have been variations in oxide weight gain and bubbles. If further experiments in these areas do not prove fruitful, it will be necessary to establish separate settings for each code and to process each code individually. Reducing the pre-furnace processing time is a problem of shop scheduling and as such will not be treated in further detail in this report.

No electrical, mechanical, or maintenance problems of any kind were experienced on the furnace after the shop trial period was completed.

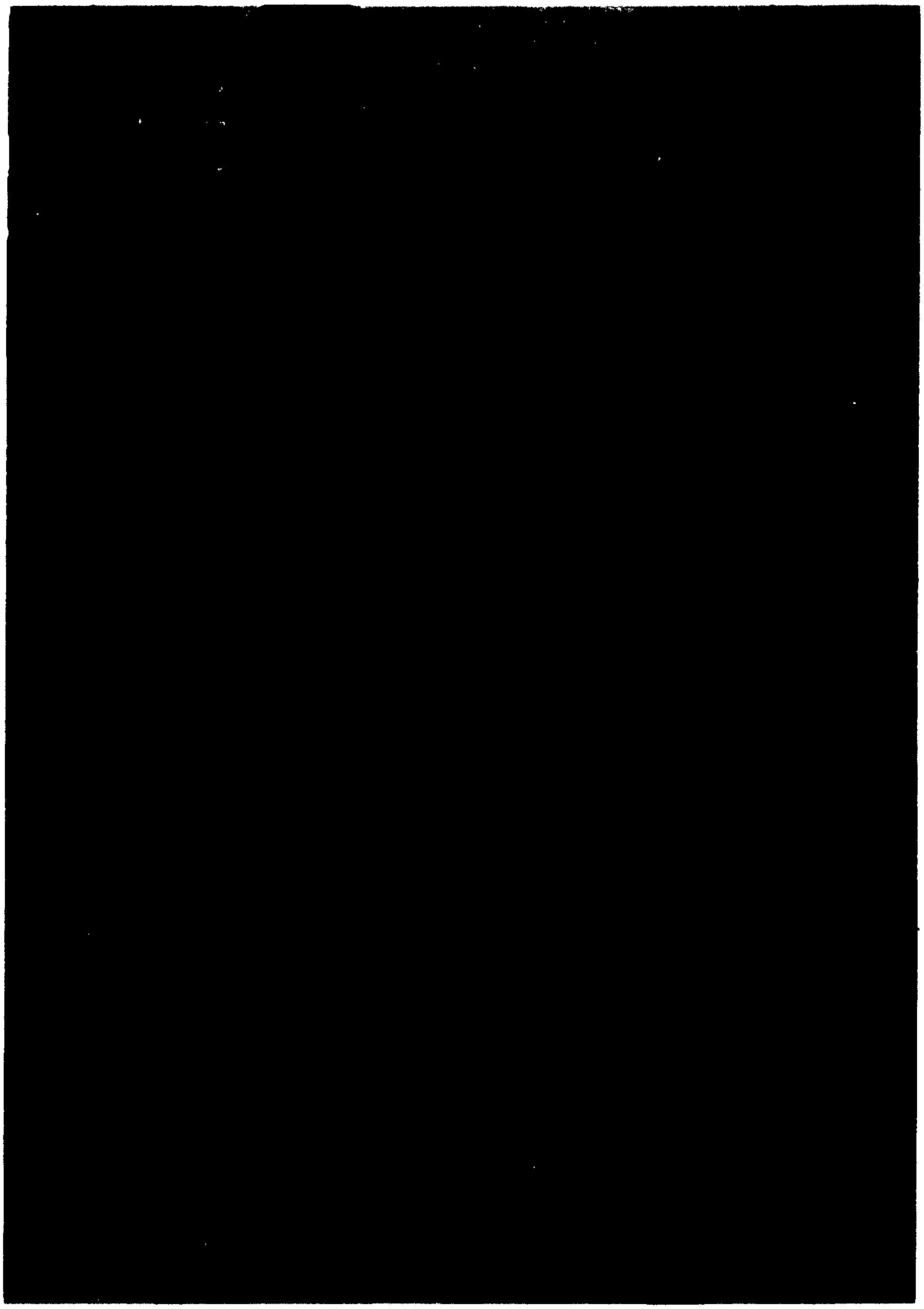
VIII Evaluation

Mechanically and electrically the furnace has proven 100 percent reliable. Once controls are set by engineering, no operator knowledge is required on the job. The operator is required only to load and unload the furnace.

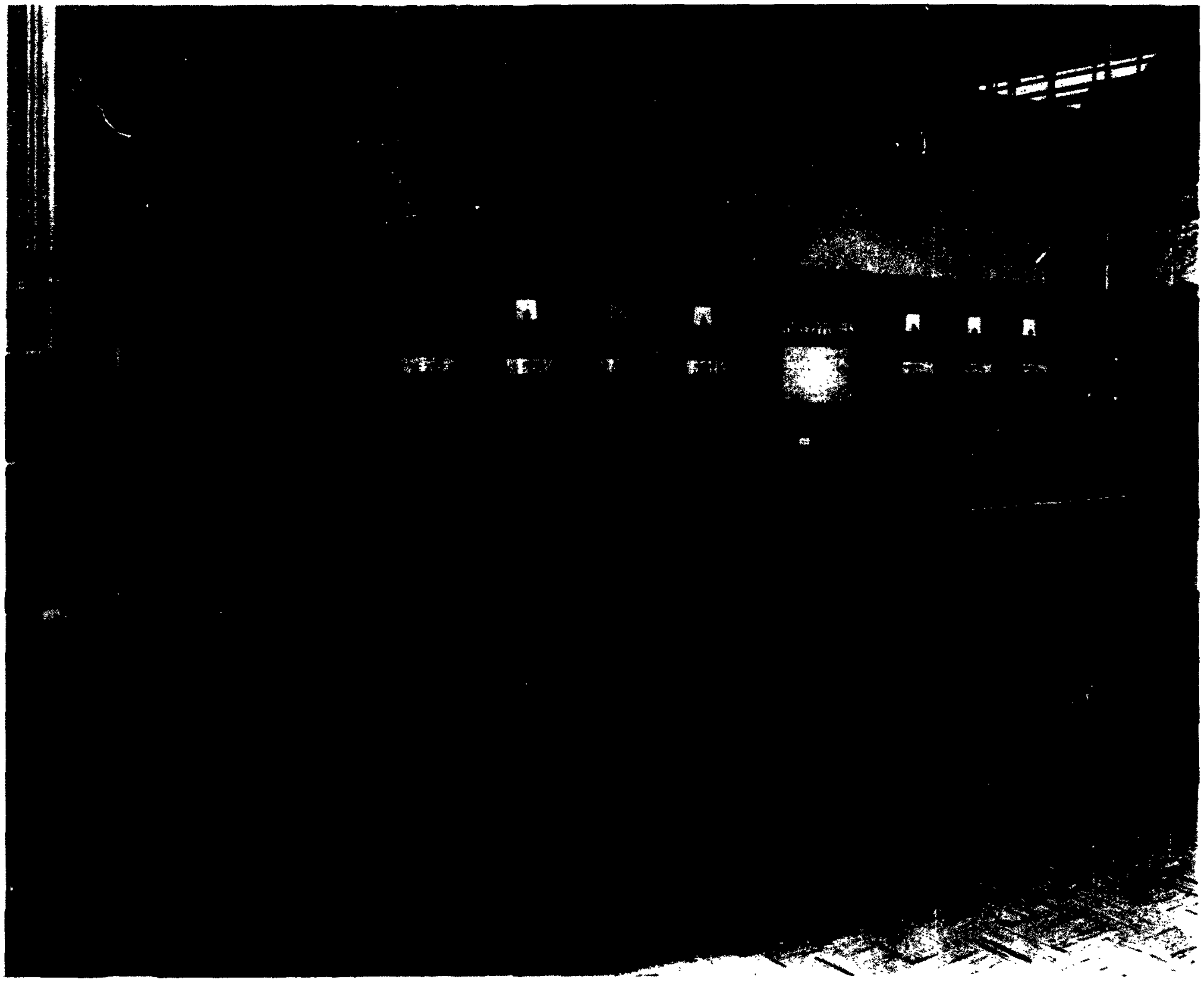
It must be emphasized that this is an entirely new processing sequence for mass production and as such the shop scheduling and compatibility problems of different headers must be solved before the full potential of the furnace is utilized.

IX Conclusion

As mentioned in the previous section, the furnace, per se, is meeting its initial objective of oxidizing and glassing with 100 percent operating reliability. No furnace alterations or modifications are contemplated at this time. Processing techniques of the parts themselves must be streamlined to provide the furnace with suitably prepared metal surfaces prior to the furnace processing. If necessary, the various codes will be run at separate specified times to take advantage of individual optimum conditions.



HEADER GLASSING MACHINE
FIGURE 3.6-1



CONTROL PANEL OF HEADER GLASSING MACHINE
FIGURE 3.6-2

SECTION 3.7

HEADER LEAD TRIMMING

Q. L. Schmick

I General

II Description of Machine

III Machine Development

IV Operational Problems

V Evaluation

VI Conclusion

VII Illustrations

HEADER LEAD TRIMMING

I General

The Header Lead Trimming Machine combines the five operations which prepare the unplated header for subsequent processing. A single operation is used to trim the emitter and base leads in preparation for Wire Bonding. Collector lead welding, which involves the four remaining operations, creates an ohmic contact between the platform of the header and the isolated collector lead. In so doing, this lead has to be accurately processed in preparation for a reliable weld.

The manual process had rates and yields which were too low to meet anticipated Nike-Zeus production requirements. Since maximizing the yield increased the output to only half of this requirement, increased rates were also required. This was accomplished by eliminating many loading and transferring functions which are inherent in the manual process. With an improved yield and a greatly increased rate, this process was compatible with the mechanized production requirements. The machine was rendered obsolete when the header design was changed to a butt-welded collector lead.

II Description of the Machine

All operations of the Header Lead Trimming Machine are performed by single turret, multiple station, intermittent motion machine (Figure 3.7-1). This turret has eight nests mounted on its periphery (Figure 3.7-2). These nests are designed to accept an oriented header, clamp and hold it in this position, while allowing the processing tools access to perform the operations. These tools are mounted around the turret (at appropriate stations) and are individually powered. Control of these stations, however, originates from a cam actuated switch which is located adjacent to the mainshaft.

To load, the operator places a header against the front face of the loading finger which has a groove to locate the collector lead (Figure 3.7-3). The emitter lead then rests against a flat portion of the finger which was provided to prevent the header from turning during the loading operation. The operator then depresses the safety switch and the cycle button to initiate the cycle (Figure 3.7-1). In the first portion of the cycle, the turret indexes to present an empty nest to the loading station while opening the clamp. During the second portion of the cycle, the turret dwells long enough for the various mechanisms to complete their operating cycles. In the loading mechanism, a 1/20-horsepower, 29-rpm motor drives a single revolution clutch. When this clutch is released, the load cam makes a single revolution allowing the spring powered load arm to advance supplying a forward motion to the drive link and, subsequently, to the load finger. With the aid of an accurate stop, the header is accurately oriented in the nest. The load finger trips a switch which in turn causes the spring loaded clamp to hold the header flange. The header is now rigidly and accurately held. Since the clamp is thinner than the header, there is sufficient clearance for access of the tooling which performs the subsequent processing. Finally, the load mechanism returns to its original position and the tools are clear for another header.

During the next cycle, the header is indexed to the next station. Although this station is referred to as an idle station, it is used to check the location of the collector lead. A rigidly mounted switch is placed such that an accurately placed collector lead does not depress the switch actuator. If, however, a collector lead actuates the switch, it is necessary to clear the nest before the next cycle can be initiated.

At the trim station, after the next index, the three leads are cut off to a predetermined length. This station has a vertically mounted, high speed grinder motor eccentrically pivoted and driven through a linkage by a cam. Another 1/20-horsepower, 29-rpm motor drives a single revolution clutch which, in turn, drives the trim cam. An adjustable link with a roller follower determines the depth of cut while the cam itself determines the feed of the trim wheel. This wheel is a .010-inch thick rubber bonded 180 grit carborundum pen slotting wheel. It is mounted on the spindle of the high speed (16,000 rpm) motor which, in turn, is mounted on an adjustable slide. This assembly may be adjusted to change the height of the cut-off and is locked to insure accuracy of the trim. At the present time, the height has been set at .160 inch. When the main cam actuated switch is tripped, the single revolution clutch is released and the 29-rpm motor drives the cam. The trim head is then driven forward by the cam and the carborundum wheel trims the leads. A spring returns the trim head while a dust collector removes the particles which result.

The same dust collector is used to remove particles from the notching station. This station is similar to the trimming station. The wheel is set to the notch height of .125 inch. The wheel, which is adjusted to penetrate the collector lead only .010 inch, makes the notch and returns to its normal position.

Next, the header is indexed to the bending station where the collector lead is bent 90 degrees. At this station, a 60-rpm motor drives a bending arm which has an adjustable tip. This tip is adjustable for both the height and the preferred orientation of the collector lead in the horizontal plane as shown in Figure 3.7-4. The tip bends the collector lead as it passes over the lead. The motor starts when the main switch is tripped and is powered for approximately one-half of a revolution. At this time a cam, mounted on the motor shaft, depresses a cut-off switch and the motor is allowed to drift to a complete stop.

The next cycle indexes the header to the welding station and welds the collector lead to the platform. This station is powered by a 1/3-horsepower, 30-rpm motor which drives the bottom electrical contact onto the front of the nest while the collector lead is depressed by the top electrode. To protect the electrodes, a switch is used to detect the presence of a header in the nest as it is indexed into this station. In the event that a header is not present, this switch prevents actuation of the welding mechanism. If, on the other hand, the mechanism is clear for running, the welding cycle is initiated. A single revolution clutch is released and the motor drives a cam shaft. The weld firing cam is also mounted on this shaft. A simple lever action is used to translate the cam motion to the upper electrode and lower electrical contact. The electrode is spring mounted to supply the proper welding pressure in spite of slight variations of header height. The lower electrical contact is also spring mounted and is rotated 5 degrees in a wiping action to insure a good ohmic contact between it and the nest. After the weld is completed, the welding mechanisms are returned to their normal starting positions.

At the next station, the header is unloaded from the nest and allowed to drop into a bin. Just before the index is complete, a fixed cam under the turret actuates the unloading mechanism and lifts the header hold-down clamp. The header is then unloaded by a cam actuated ejector. During the turret dwell time, air is blown through the nest to insure that the header has been unloaded and to clean the nest.

The final index places the empty nest at another idle position. Like the first idle station, however, this one also has a function. A switch is mounted such that the actuator arm is depressed if a header remains in the nest. If a header is in the nest at this position, the switch prevents further cycling until the nest is cleared.

The operators major duties are to load the machine and to initiate the cycle. Aside from this, however, minor duties include machine surveillance and clearing nests as required. For safety two cycle switches are used. They are positioned such that the operator must use both hands to initiate the cycle. This was done to eliminate possible injury to the operator's hands. The control panel, which is within easy reach of the operator, houses the indicator lights which denote the condition of the machine.

III Machine Development

When this process was done manually, four separate tools or fixtures were used to perform the four operations - trimming, crimping, bending and welding (Figure 3.7-5). A horizontal turret-type bench fixture was used to trim the three leads .160 inch above the header flange. The collector lead was then crimped by a modified wire clipper which coined two diametrically opposed notches into the sides of this lead .125 inch above the flange. Lead bending was done manually with tweezers after which the collector lead was welded to the platform with a "Tweezer Weld". To provide clearance for subsequent processing, the collector lead height was limited to a maximum of .128 inch from the header flange. The location of the crimps, radially around the lead, and the subsequent accuracy of the bend affected the ultimate location insure that the header has been unloaded and to clean the nest.

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The primary objective was to increase the yield as nearly as possible to 100 percent by reliably locating the collector lead weld. This alone, however, did not fulfill the anticipated production requirements of 600 units per hour. Therefore, a secondary objective became necessary: The rate was to be increased by elimination of the many loading, unloading and transfer operations required to complete the process manually.

A decision to use welding equipment familiar at Laureldale eliminated the necessity to perform feasibility studies for this operation. Feasibility studies were conducted for the loading, bending and trimming only. The trimming, which employs the same basic approach as the bench fixtures, had produced an objectionable burr on the end of the lead. A study of the problem resulted in the introduction of a lead back-up plate which supports the lead during the cutting cycle of the trimming operation. This solved the problem. Since the notch in the collector lead did not require a deep cut, there was little burr; consequently, there was no need to support this lead while notching. The feasibility studies conducted for loading proved that the original concept would provide a reliable mechanism with only minor changes. The high speed grinding motors used for both the trimming and notching operations were quite noisy. Special muffles were designed and installed on the motors. They reduced the high pitch noise to a tolerable level, but did not eliminate it as some noise still escaped from the air exhausts needed to cool the motors.

Although the original concept of the bender was a rigid structural member, it was replaced by a motorized concept during the design phase.

This was done to make the bending operation more flexible. At the same time, the loading mechanism was also changed because the original concept required more room than was reasonably available in the machine.

IV Operational Problems

Once prove-in was complete, the machine was installed in the production area for shop trial runs. After a few hours the operator could handle the machine alone, but it took about a month before she could develop the skills necessary to operate it at the forecasted rate.

Burrs formed during the trimming operation were troublesome on the base and emitter leads. Those burrs formed at notching were not troublesome because subsequent bending and welding operations masked them. Initially, burrs were as large as .008 inch. The specified limit is .005 inch. Extra care in adjusting and aligning the lead back-up plate overcame the problem and reduced burrs to .003 inch.

After a few months of shop trial, the length of the trimmed leads was changed from .160 to .114 inch to accommodate the header for wire bonding to the tops of the trimmed leads. This change, however, obsoleted the trimming station because the trimming wheel had to trim behind the collector lead which was .125 inch high. The machine was still used for notching, bending and welding the collector lead. The other leads were then trimmed in a secondary manual operation.

Shortly after this change the header was further redesigned to eliminate the bent and welded collector lead design in favor of a butt welded design. This change rendered the remaining stations obsolete. The machine was then declared obsolete and removed from service.

V Evaluation

While this machine was in service, evaluations were made of its effect on the product and its mechanical capabilities. Results indicated that the machine could not be substantially improved. It was mechanically and electrically reliable while operated on a single shift basis. Continuous operation for a two or three shift period was not tried, but it appeared that similar reliability could be expected.

By eliminating repeated header handling, this machine almost doubled the gross output per operator. It also increased the net output by markedly reducing rejects at the welding operation. During manual lead welding, weld placement could be varied by the operator. Consequently, header glass often cracked when a weld was made too close to the lead holes in the platform. Mechanizing the trimming operation improved accuracy slightly but did not affect the yield significantly.

Certain improvements could be designed into similar Header Lead Trimming Machines. Although the loading mechanism of this machine operates properly, it is structurally weak. Strengthening members were added, but spatial limitations restrict their size.

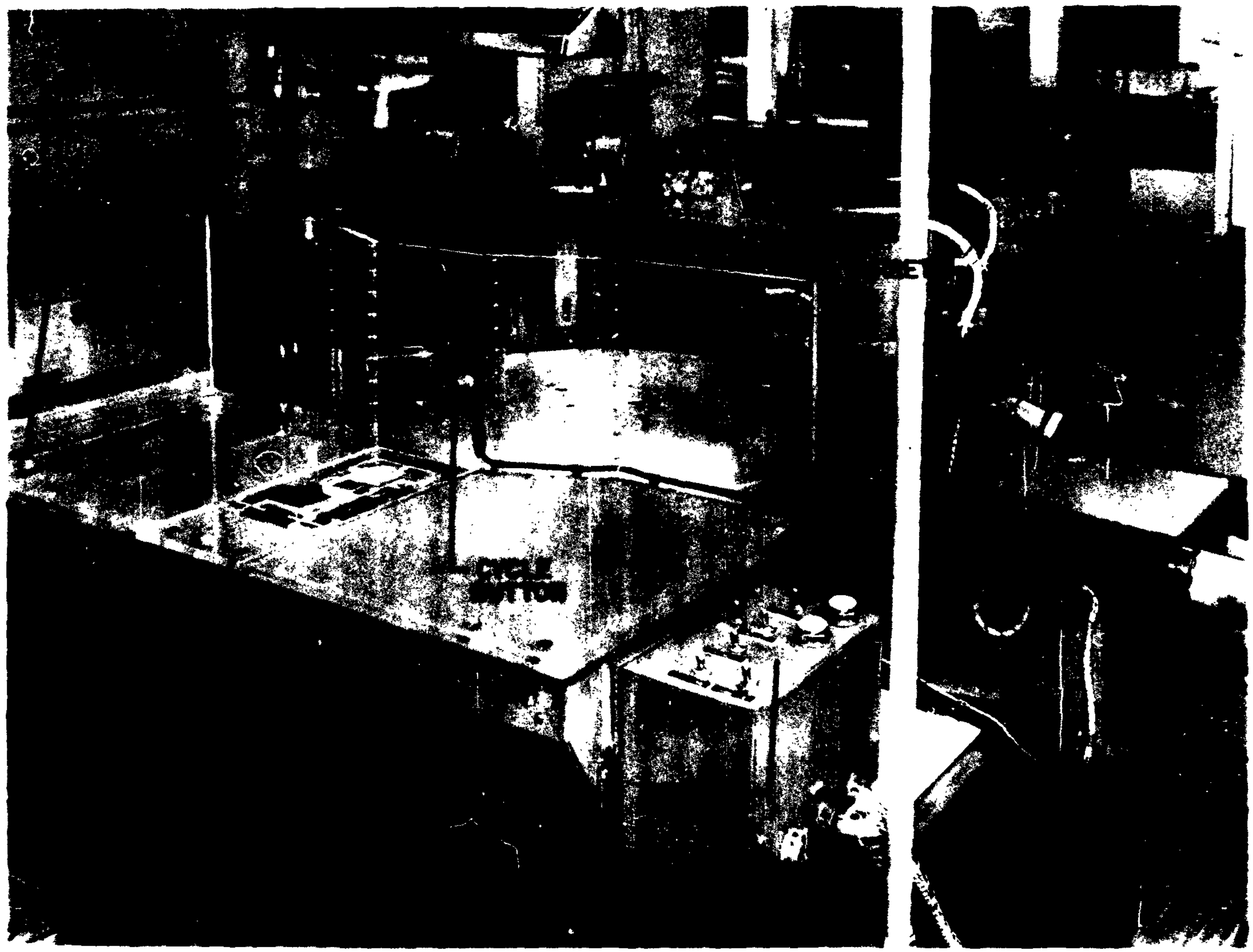
The welding station, which is operated mechanically, is more complicated than a pneumatic or a hydraulic design would have been. So, modifications could simplify it; however, this station is reliable. Cracked glass still occurs after welding if weld placement is not controlled. To minimize glass cracking, the setting of the grinding wheel at the notching station must be monitored continuously. A simple screw adjustment will correct for wear on the grinding wheel and eliminate the problem.

The indexing turret, which forms the base of the machine was designed by a subcontractor. After considerable prove-in, it met expectations and performed as well as equipment available commercially. Cost of another machine could be reduced appreciably by redesigning the machine for a standard commercial turret.

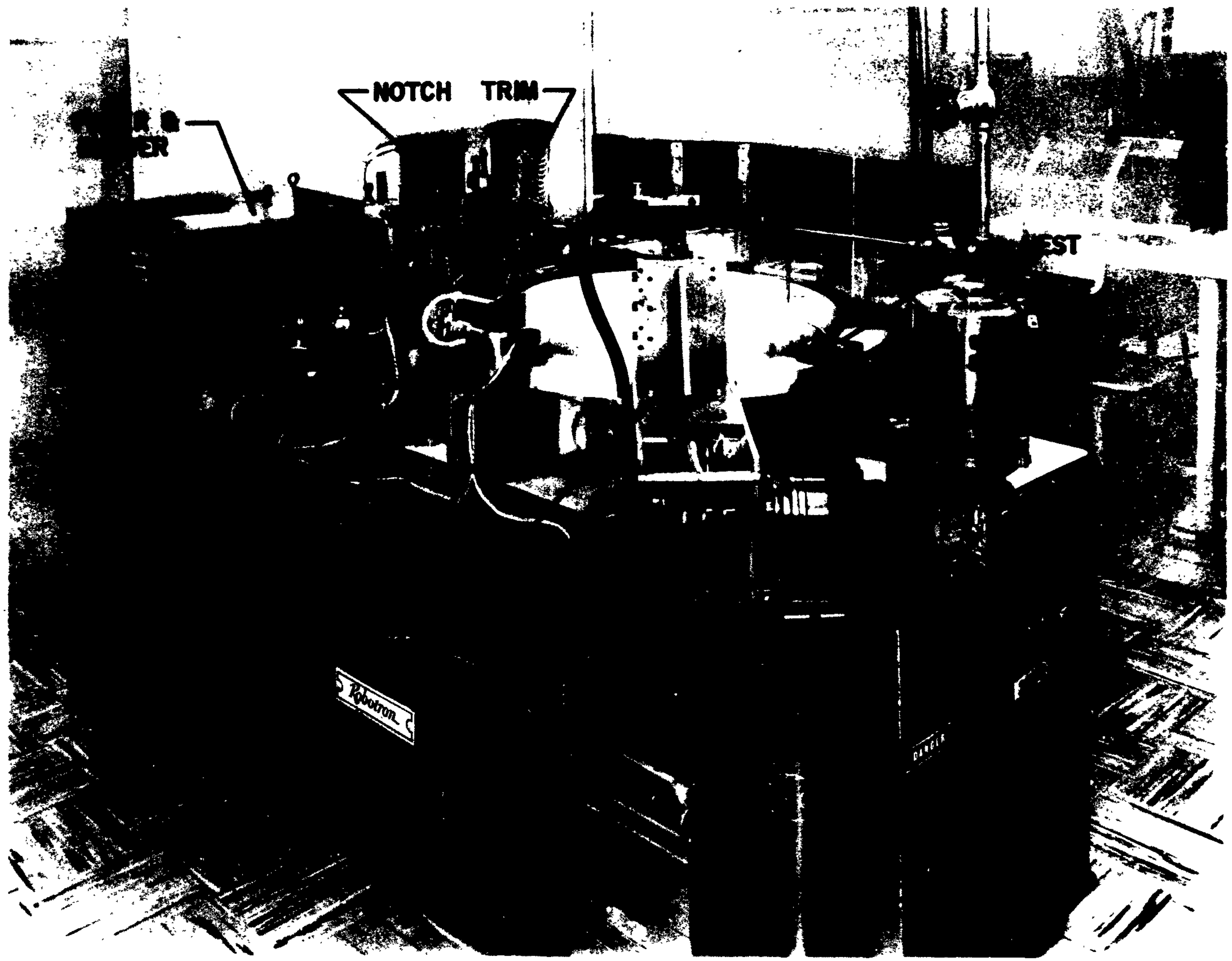
VI Conclusion

Shop trials have demonstrated that the Header Lead Trimming Machine has the high-volume production capability required so long as weld placement is controlled. The net output per operator was more than tripled by mechanizing the operation; it increased from 184 to 580 units per hour. This marked increase was made possible not only by increasing overall efficiency but also by markedly decreasing header damage or destruction during lead welding. More uniformly and accurately placed lead welds made this decrease possible.

Although a reliable machine is provided, two design changes to the header have made the machine obsolete: butt welding the collector lead and shortening the two internal leads. Certain machine components can be improved but this is not practical now. Consequently, lead trimming remains a semiautomatic operation and collector lead attachment has been modified and mechanized as indicated in Section 3.4, Platform Lead Welding.



HEADER LEAD TRIMMING MACHINE - FRONT VIEW
FIGURE 3.7-1



WORK STATIONS OF HEADER LEAD TRIMMING MACHINE
FIGURE 3.7-2

HEADER POSITIONED AT LOADING STATION

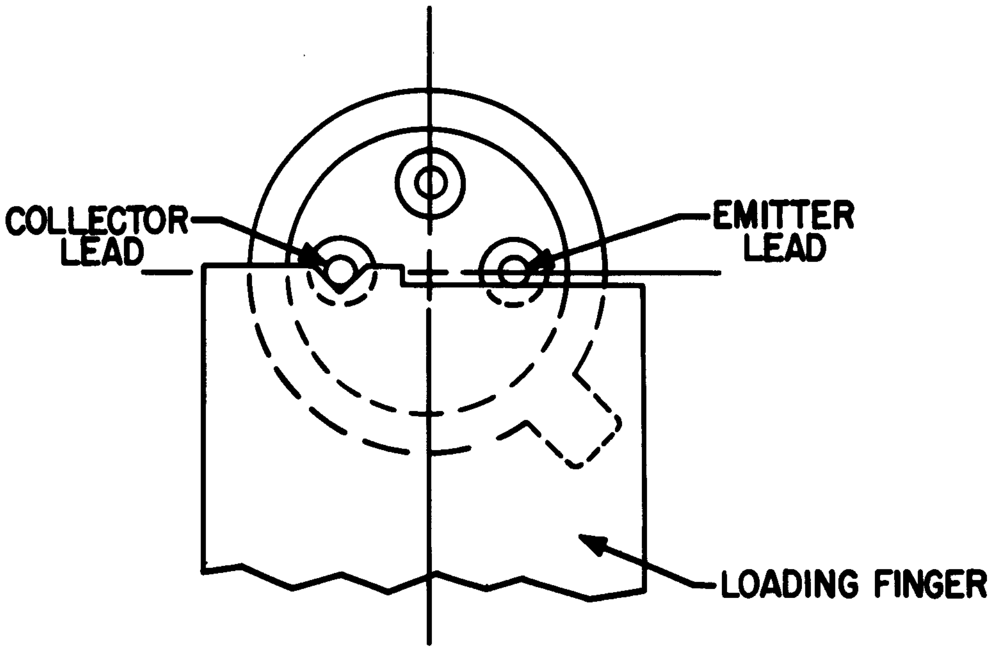


FIGURE 3.7-3

COLLECTOR LEAD ORIENTATION BEFORE WELDING

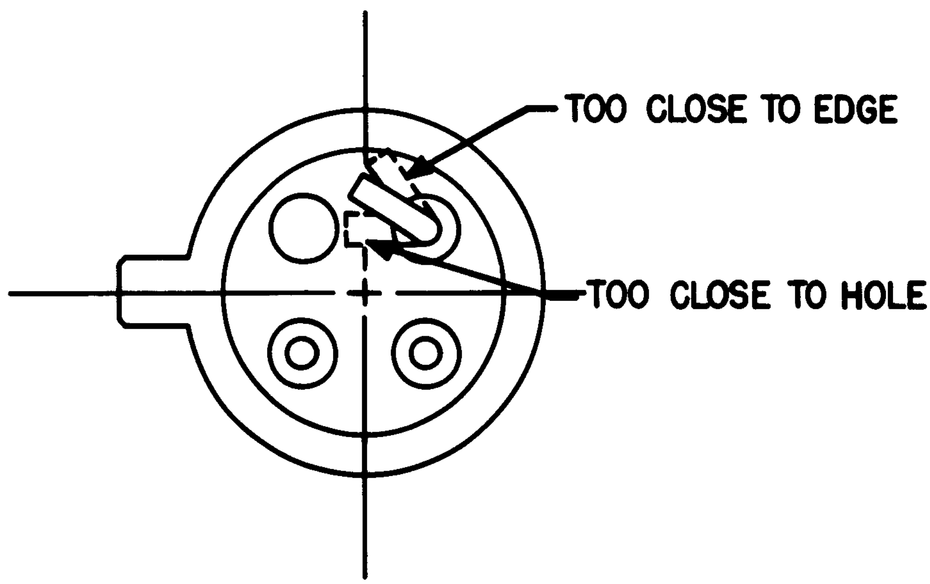


FIGURE 3.7-4

HEADER LEAD TRIMMING PROCESSES

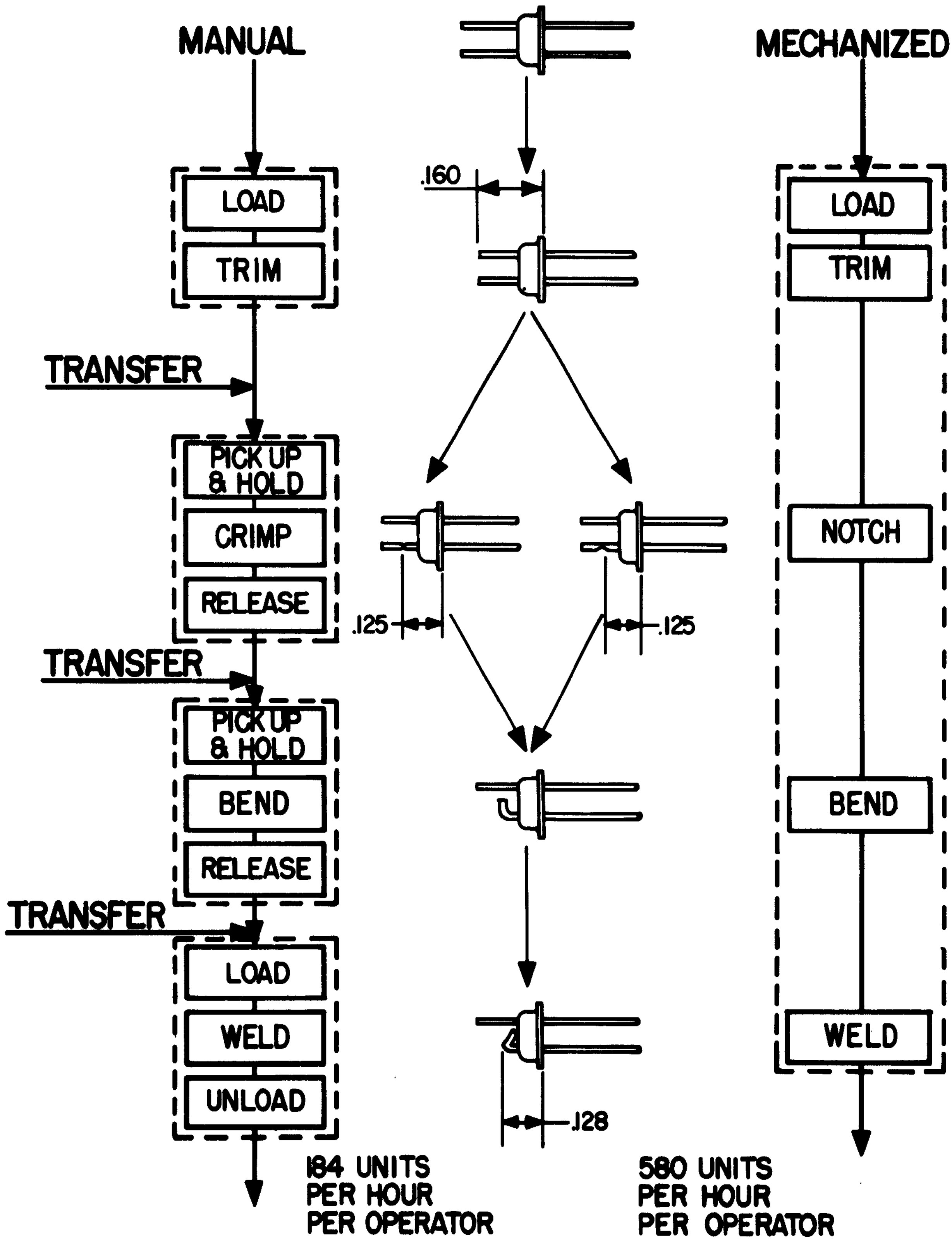


FIGURE 3.7-5

SECTION 3.8

STRIP PERFORATING AND WELDING

R. P. Loeper

STRIP PERFORATING AND WELDING

I General

The Strip Perforating and Welding Machine prepares headers for the Gold Plating operation by welding the tips of the leads to a steel band. This band with headers attached is then coiled on a reel which is the input to the Header Continuous Rack Plating Machine. The Strip Perforating and Welding Machine also perforates the steel band with exactly positioned holes prior to the Welding operation. Headers are manually loaded at a gross rate of 875 per hour for the TO-5 type and 1750 per hour for the TO-18 type.

The mechanized assembly of the transistor demands headers with exceptionally straight leads and a more uniformly plated surface. This machine in conjunction with the Header Continuous Rack Plating Machine produces headers exhibiting these qualities. Two Strip Perforating and Welding Machines were provided to supply the strip assemblies needed for the Header Continuous Rack Plating operation.

Loading headers into the machine and maintaining accurate tape indexing presented problems during the course of the project. Automatic header feeding remains as a problem to be solved during the Phase 2 portion of the Contract.

II Machine Description

The machine base resembles a double pedestal desk with a hardwood top, 5 feet long and 3 feet wide. These pedestals, aside from supporting the top, also house some of the electrical components. The welding transformer and controller are mounted in the right pedestal and the fuse box and take-up motor are located in the left pedestal. An electrical control box containing the take-up drive rheostat and operating switches is located on the table top within easy reach of the operator. Figure 3.8-1 is an overall view of the machine showing the control box on the table top and the controls for the welder in the right pedestal.

The main mechanism of the machine is assembled on a solid base plate on the table top. It consists of the punch and die, the welding mechanism, the header indexing and locating block mechanism, and the separating rollers. A motor and gear reductor connected through a single revolution clutch drives the various components.

One-half-inch-wide by ten-thousandth-inch-thick steel tape is drawn from a coil supported on a suitable rack atop the table. This tape is fed into the punch and die in a vertical position. A hitch feed mechanism automatically indexes the tape after an initial length is punched manually. A small escapement working in the punched holes and synchronized by the punch mechanism allows the tape to move a fixed distance after each perforating cycle.

Headers are manually loaded into locating blocks mounted on a chain. The locating blocks feed the headers to the welding station as the chain is indexed and maintain header alignment during welding. The locating blocks and the steel strip are synchronized by moving both with the same indexing lever. After the headers are indexed into the welding station, the movable electrode moves laterally and pushes the strip and lead ends of the header into intimate contact with the stationary electrode and the welding cycle is activated.

As the strip leaves the welding mechanism, it passes through a header separation station which alternately deflects the headers to the right and to the left of the strip. Cogged wheels are used to deflect the headers as the strip passes between a sprocket and capture roller. The strip is twisted horizontally for reeling as it leaves the separation station. Figure 3.8-2 shows a close up of the strip with welded headers emerging from the separating rollers with the main mechanism in the background.

Two 24-inch diameter reels are mounted under the top at the back of the machine. One reel is driven by the take-up motor and winds the strip as it is indexed through the machine. While the prepared strip is being reeled, a ribbon of filler material, supplied from the adjacent reel, is wound sandwich fashion between layers of prepared strip. This filler prevents the bending and tangling of the headers on a reel.

Chains with two types of loading blocks are provided to supply headers to the welding station. The one type of loading block is designed for TO-18 headers and aligns headers on 1/4-inch centers; the other type, designed for TO-5 headers, spaces the headers on 1/2-inch centers. When running the TO-5 headers, a control is set so the welder fires only when a header is at the welding station.

Loading the locating blocks with headers, monitoring the work coming from the machine, adjusting the potentiometer for take-up clutch power, and obtaining help for changing reels constitute the duties of the operator. With the exception of reel changing, women can operate the machine. Male assistance is required to change reels since the loaded reels weigh 44 pounds. Maintenance of the machine consists principally of sharpening of the punch and die, and changing electrodes.

III Machine Development

Development of the Header Continuous Rack Plating process created a need for a machine to attach oriented headers to a continuous band of

1/2-inch steel perforated with small square holes. Development was started by welding the headers on a manually operated bench welding machine. It was found that a 2-1/2-KVA transformer and a synchronous timer were amply suited for making the welds.

The most unique problem anticipated with the conception of the machine was a system for header feeding. This system would have to feed headers in an end oriented position, hold the platform a fixed distance from the strip, and allow them to be fed so they are spaced on 1/4-inch centers after welding. The first concept on a header feed was a chain with slotted blocks. These blocks would have the headers lying in the slots with the platform held by a light spring against the edge of the block. With the slots on 1/4-inch centers, the headers would be lain into the slots and fed to the weld station. Only a slight change was made to this plan during final design. The blocks were turned 90 degrees so that the headers were suspended by the platform in the slots.

The concept of punch construction was to have a punch and pilot pin mounted in a heavy ram as part of the main mechanism with the die block mounted on the sub-base. The pilot pin was to align the strip using the previously perforated hole as the aligning medium.

The experimentally welded units showed that with long leads, headers would occasionally have their platforms rubbing one another. Slightly staggering the headers after welding them to a strip proved to be a remedy for the problem. After study, it was decided that a pair of cogged rolls could be used for staggering the headers; the cogged rolls would bend one header slightly to the right and then the next header a like amount to the left.

IV Operational Problems

The first problem encountered during prove-in of the machine was difficulty in feeding the 1/2-inch steel tape. The machine was built with strip guides that were apparently set too close. When the tape was bent slightly, the force needed to pull a bend through the guides was excessive, and the strip would not index the full distance. This trouble caused improper indexing which, in turn, caused additional trouble. The pilot pin, in the event of faulty indexing, would not pass through the previous perforation, instead it would dimple the material between perforations causing another impediment to free travel of the strip. After additional clearance was added to the guide, the trouble occured less frequently.

Due to these problems, design of the strip indexing system was changed. A stop pin was added to the punch and die; this stop pin is located in the die cavity at the position of the previously punched hole. A friction surfaced roller was substituted for the sprocket that was being used to index the tape through the machine. The new indexing system works in the following manner:

On the forward stroke, the punch perforates the tape while the pilot pin, slightly ahead of the punch, pushes the stop pin from the previously perforated hole and aligns the strip for perforating. The stop pin is then pivoted slightly toward the punch by a spring. After the hole is perforated and the punch and pilot pin are withdrawn from the strip, the stop pin rides on the portion of strip between perforations. When the punch is almost fully retracted, the indexing system moves the chain with locator blocks attached and the friction wheel pulls the strip. As the strip advances, the stop pin enters the newly perforated hole and arrests it. This new design has greatly reduced the indexing and feeding problems.

Another problem was encountered with the clutch-driven tape-up reel. The original leather clutch slipped as the reel neared its capacity; therefore, a magnetic clutch was built into the machine replacing the original clutch and solving the clutch slipping problem.

The original design of the machine had a large magnetic roller which was used to facilitate feeding of headers to the holding blocks. This roller, with its strong magnetic field, caused bent leads while transferring headers from the roller to the holding blocks. With the large magnetic roller removed, a trial run was made using manual loading of headers directly onto the locating blocks, and it proved to be a more acceptable method of loading the headers. As prove-in progressed, it was found necessary to use .015-inch-thick material on the Header Continuous Rack Plating Machine; additional tape feeding problems again occurred occasionally because the friction drive did not create enough friction to pull kinked portions of the .015-inch tape through the strip guides. A sprocket driven by a hitch feed mounted on a spring loaded arm replaced the friction drive.

Eventually progress on feeding tape through the Header Continuous Rack Plating Machine allowed .010-inch-thick tape to be used, thus .010-inch tape is now used for the Strip Perforating and Welding. This change has improved the performance of both machines without requiring any additional changes.

V Additional Developments

During prove-in, the possibility of plating the TO-5 header was investigated. This header with its larger diameter platform and shorter leads introduced a major handling problem for the Strip Perforating and

Welding Machine. A new set of blocks with the header spaces now milled on 1/2-inch centers and corrected for the new lead lengths was designed and built. With the 1/2-inch centered headers, it was also necessary to incorporate a switch to allow for changes in the welder firing circuit. The original machine fired the weld current each time the welding electrode came forward; however, for the TO-5 headers, the welder had to be fired every other time. This additional switch, connected in series with the original firing switch makes it possible to fire the welder only when a TO-5 header is indexed to the welding position. These changes solved the feeding and welding problems which arose while modifying the machines to process TO-5 headers. New filler tape with a heavier cross-section to allow for the larger diameter header was also provided.

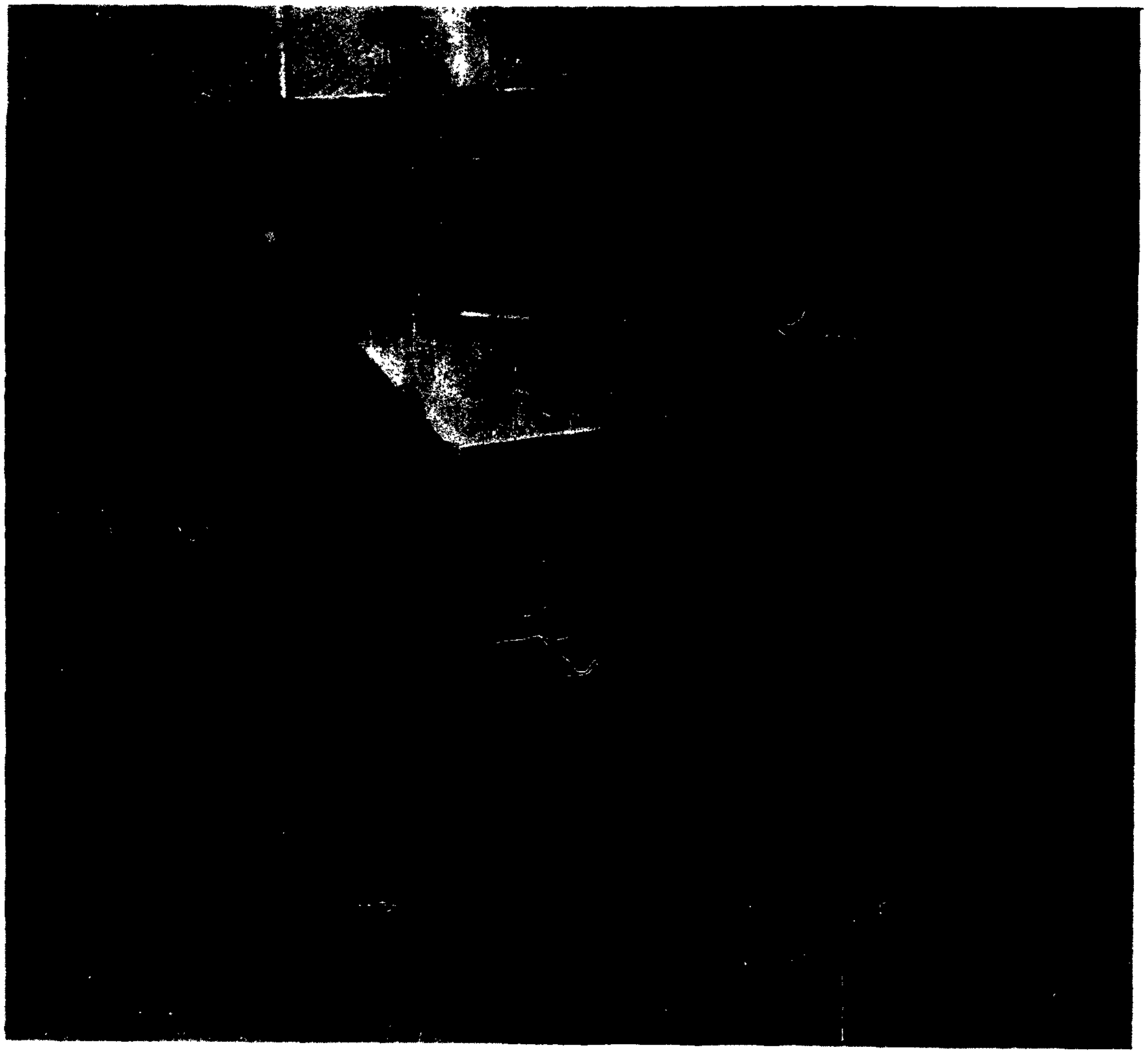
When the lead length of the TO-18 header was changed, a new set of blocks was made and filler tape with a different cross-section was procured. The knowledge obtained from the investigation of the TO-5 header was utilized for this redesign. During these developments it became apparent that a second machine would be needed to balance the capacity of the Strip Perforating and Welding with Gold Plating operation. So a second machine was built. This machine is a duplicate of the first, and incorporated all the changes made to date.

VI Conclusions

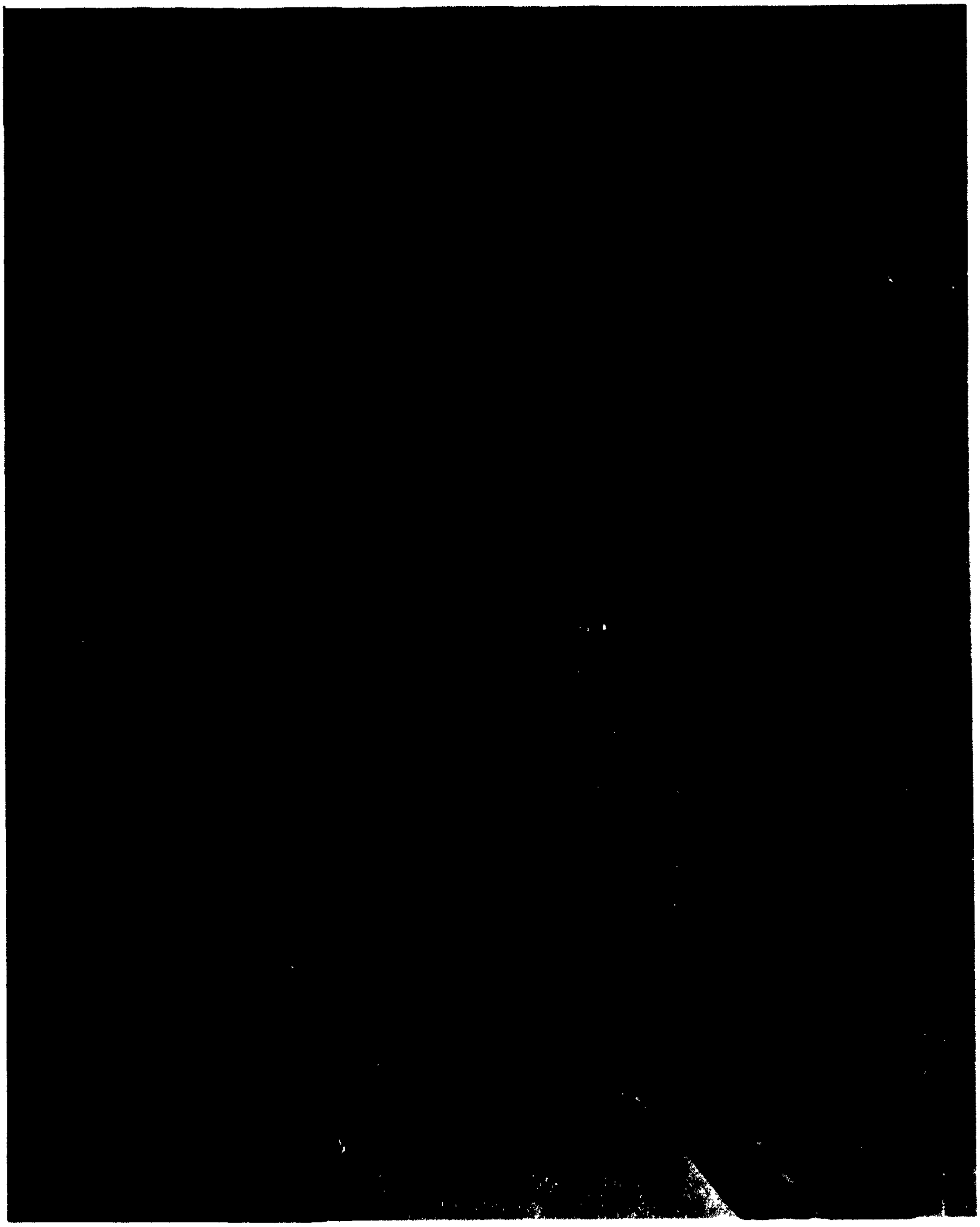
Personnel can be readily trained to operate the machine. Maintenance during the shop trial runs included mostly replacing and redressing electrodes and resharpening of the punch and die. Occasionally, trouble occurred from faulty indexing. In general, when headers with straight leads perpendicular to the platform were used, the machine worked well; bent leads on headers tend to jam in the locating blocks and, at times, the leads are bent to such a degree that the welding electrodes miss the leads entirely.

The original goal set for these machines has been realized. Thousands of headers were prepared for strip plating while keeping the leads straight. The machines are designed to run at a net rate of 1,400 TO-18 headers per hour welded to the strip. During shop trial run a net rate of 1,200 headers per hour was held for over 100,000 pieces. For TO-5 headers which are welded on only every other stroke this rate is halved.

Additional work contemplated for continuation under Phase 2 would be the incorporation of an automatic header feeding device, improvement in the punch and die to provide for a higher number of perforations between sharpenings, and an increased TO-5 production rate.



STRIP PERFORATING AND WELDING MACHINE
FIGURE 3.8-1



STRIP-WELDED HEADERS EMERGING FROM SEPARATING ROLLERS
FIGURE 3.8-2

SECTION 3.9

HEADER CONTINUOUS RACK PLATING

R. P. Loeper

SECTION 3.9

HEADER CONTINUOUS RACK PLATING

R. P. Loeper

HEADER CONTINUOUS RACK PLATING

I General

The Header Continuous Rack Plating Machine cleans and applies a uniform gold plate on TO-5 or TO-18 headers and at the same time keeps the header leads straight. The headers are welded to a steel strip in the Strip Perforating and Welding Machine. The steel strip is then utilized to transport the headers through the Header Continuous Rack Plating Machine. This unique method of material handling provides straight leads and uniform plating.

The machine replaces a batch-type barrel plating process which tangled and bent the header leads and produced variations in plating as the headers were tumbled in the plating barrel. To date, headers plated on this machine are superior to barrel plated headers in both lead straightness and quality of plated surface.

Feeding of the steel tape with the headers attached presented the most difficult problem on the project. Corrosion resistance remains as a problem; this area needs additional improvement as the corrosive agents and atmosphere in and around the machine are more active than anticipated.

The machine is versatile in that both TO-5 or TO-18 headers can be processed by the machine. The only change necessary to shift from processing TO-5 or TO-18 headers, or conversely, is simply changing the rectifier output. The machine provided is capable of plating over 1900 TO-18 headers per hour or half as many TO-5 headers.

II Description of the Machine

The main body of the machine is "U" shaped with the open part of the "U" facing the control console. It covers an area 31 feet long and 11 feet wide with a 4-foot aisle up the center of the "U". The electrical console is 3 feet wide and 10-1/2 feet long and is separated from the legs of the "U" by a 3-foot aisle. Figure 3.9-1 is a schematic of the machine and Figure 3.9-2 is an overall photograph of the machine proper.

Specific features built into this machine are:

1. A method of cleaning and plating that would assure relatively straight leads.
2. A plating process that presented very nearly identical conditions to each header thus assuring a more uniformly plated part.
3. A method to economize on the amount of gold to be plated.

A reel stand at the input end of the machine plays the steel band assembly into the machine with a magnetic brake providing an adjustable drag on the reel. On this same stand another reel, driven through a magnetic clutch, takes up the ribbon of filler tape that is played out with the steel band. The clutch provides the necessary reel speed needed as the reeling diameter changes. A similar reel stand is provided at the exit end of the machine with the clutch and brake action connected to the opposite reels. Each of the reel stands have provisions for two sets of reels to aid in cut-over when changing reels.

A welding station consisting of a welding head, transformer, and weld current timer is located between the input reel stand and the first tank. Here, the ends of the steel strip are welded together to form a continuous band. Besides transporting the headers through the machine, this steel band also acts as a part of the electrical circuit connecting the headers by means of their welded connection, the strip, guide rollers, contact springs, and suitable wiring to the rectifier.

At particular points in its travel, the strip runs submerged beneath rollers. At other points the strip moves through the tanks in a vertical position with the headers platform down and the strip above the liquid level. On leaving these tanks the strip is twisted to a horizontal position, by warping it between guide rollers so that the headers clear the tank ends. Untwisting the strip lowers the headers into the next tank. Figure 3.9-3 pictorially shows this action.

Each of the baths has a work tank and a reservoir. The solution is transferred to the work tank from the reservoir by a suitable pump. Weirs are used in the work tanks to control the solution level. The plating solutions are filtered before being discharged to the work tank. Solution temperature is maintained by steam coils in the reservoir, with suitable temperature sensing controls regulating steam supply. A small drain tube allows the solution to drain into the reservoir on machine shutdown.

Suitable spray systems are installed for rinsing between baths. Immersion rinse baths follow the plating baths to salvage gold salts and plating solution that are carried out on the parts.

Drying the parts is accomplished, first, by submitting them to a steam wipe thus removing the excessive water and elevating the temperature of the parts to aid in final drying. Then, an air dryer is provided for final drying; this consists of a blower for circulating the air and a 3-tier finned steam heater for heating the air.

The strip is pulled through the machine by a capstan type drive at the end of the machine. The capstans are two rubber covered magnetic rolls which allow the strip to slip if a jam occurs. Separately driven rollers, one in each corner of the "U", act as auxiliary drives. These rollers have a surface speed slightly higher than the strip speed; when help is needed, the strip is pulled tight and the friction created by the strip pulling on these rollers helps drive the tape.

A fixture has also been added for cutting the gold plated headers from the strip as they leave the machine. This fixture has a shear blade and a drive mechanism for driving and reeling the used tape.

Fumes are exhausted by a double exhaust system. The acid and alkaline fumes are carried away by one system while the remaining fumes, mostly cyanide, are removed by the other.

Two electrical systems are installed on the machine. One system, connected to the 440-volt line, is used for machine operation; 110-volt power for the rectifiers is obtained from this line. A separate 110-volt system, obtained from a 220-volt lighting circuit, is used for an alarm system to indicate component failure. Figure 3.9-4 shows an overall view of the electrical control console.

Output of the machine is a continuous strip of gold plated headers. This strip leaves the machine at a rate of 8 inches per minute producing 1920 gold plated TO-18 headers or 960 gold plated TO-5 headers per hour. The strip can then either be rolled on reels or fed through the shearing fixture where the headers are sheared from the strip, and directed into a sintering basket, 500 per basket, preparatory to sintering.

In addition to the alarm system, various safety features are incorporated into the machine. All the baths are drained into closed reservoirs when the machine is idle. A well planned exhaust system sweeps the fumes off the tops of the work tanks and also pulls a slight vacuum on the reservoirs. Following the acid pickling tank, two water rinses are used to avoid carry over of acid to the cyanide solutions in the plating tanks, one is a spray rinse and the other is an immersion rinse. The immersion rinse is the overflow type so that a level of water is maintained in the event of a momentary water shutdown.

Maintaining bath make-up, changing reels, casual inspection of machine and changing sintering baskets as they are filled constitute the main duties of the operator as the machine is running. On starting, the operator must also place gold anodes in position on the anode bars and place various components in operation.

Maintenance of the machine should be at a minimum as much thought went into the design of various components to make them as trouble-free as possible. Up to now, the ambient atmosphere with its corrosive action has been the largest problem showing up as dirt from corrosion at the electrical contacts, stiff bearings, and leaks in plumbing lines.

III Unmechanized Cleaning and Plating

Prior to the use of the Continuous Rack Plating Machine, headers were placed in metal screen trays for cleaning and barrels for plating. During the course of the project, an improved process was developed. Improvements in the latter process, where practical, were also included on the machine.

When the plating machine design was started, the manual process for cleaning and plating consisted of 16 operations. Parts were first placed in wire baskets and cleaned preparatory to plating; they were then placed in the small plating barrel and plated, first with copper (5 to 10 msi) then gold flashed, followed by gold plate to 175 msi (milligrams per square inch); the parts were then rinsed and dried. These parts were processed in lots of 500 in 270 minutes. During most of this time, the parts were in solutions; therefore, an attendant was required only to transfer parts when various cleaning and plating periods had elapsed. Figure 3.9-5 shows the parts ready to be removed from a plating barrel.

The hand process today consists of 15 operations very similar to above; however, changes in plating and cleaning solutions and reduction in plating thickness cut the time required for cleaning and plating from 270 minutes to 105 minutes. A one-inch reduction in lead length also reduced the amount of gold required per header.

Cleaning of the parts with the initial process consisted of vapor degreasing, acetone degreasing and hydrochloric acid pickling, followed by suitable rinsing. One can readily see the hazards that are presented in this process; with this in mind, hot electrolytic alkaline cleaning was substituted in the modified process.

The plating cycle during the period of the Contract was also modified eliminating the copper plate beneath the gold to improve corrosion resistance of plated headers to high temperature wet oxidation. This, in turn, required a gold striking bath having additional throwing power: throwing power being the term given to the ability of a plating process to plate into recessed areas. Here, a low efficiency gold bath is used with lower gold concentration, higher current density, and a longer strike time. This new plating procedure, with its improved corrosion resistance to high temperature wet oxidation coupled with advances made in Wafer Bonding, has permitted reducing the amount of gold on the header from 175 msi to 75 msi.

Net outputs of the manual processes were 250 headers per hour for the first process which included cleaning, plating and lead straightening and 312 headers per hour for the second process. These figures are base outputs adjusted for efficiency and yield.

One shortcoming of the barrel plating process is that it uses 18 to 30 percent more gold. In the plating barrel, contact rods are used to make electrical contact with the parts; since these rods are part of the cathode, they are plated. This gold can be reclaimed, but cost of reclamation must be considered. Another deficiency is the inconsistent plating that is caused as the parts rub on one another and lose contact with the contact rods as they are tumbled. This tumbling action also makes a knotted mass of the headers by entangling and kinking the lead wires.

IV Development

The anticipated Nike Zeus program called for high production machinery, giving a device with improved reliability. In an effort to attain a header plating machine meeting these demands, development was started on a new method of plating. The machine covered in this report is the outcome of this development and produces transistor headers with straight leads and a uniformly plated surface. Some of the first methods considered for keeping the leads straight and providing better plating were the use of spring clips or transistor sockets mounted on a chain. Later, welding headers to a steel tape was conceived and, when more fully explored, seemed to be the most practical approach. This method was finally adopted; however, early in the development when grasping of the headers by the lead tips was considered, it was pointed out that in the past this method had been rejected due to fear of plating differences resulting from the unequal current distribution in the insulated header leads and the grounded lead. Parts welded to short pieces of strip and plated in this manner proved this effect was negligible.

Various methods of carrying this strip with headers attached over or through tank walls were then explored. Parts could be fed through weirs in the tank ends; however, the necessary weir shape demanded pumps with relatively large capacity. Another plan of attach was to run the strip in a horizontal position and by means of rollers run it over the tank ends and then immerse it in the solutions; the problem presented with this approach is that the strip is also plated which then requires gold reclamation as an additional operation. The twisting or warping of the strip by suitable rollers at the tank ends resulted from the detailed study of the problem.

Another advantage of strip plating is that it permits selective plating. The 175 msi plating was needed only on the platform to furnish the surface needed for eutectic bonding of the wafer; less plating is needed on the leads. With this approach as an objective, the plating operation following the gold strike was separated into two operations: first, the entire header was plated with 70 msi; after a rinsing operation, the header entered a second plating bath where an additional 120 msi was added to the platform. This was done by adjusting the solution level in the second plating bath so that it covered only the platform. This provided a measurable saving of gold as 80 percent of the total plated area exists on the leads.

With the method of handling the headers established, layout of the machine components was started. The plating process indicated the order of operation and times needed in the baths. Immersion time and strip speed determined the length of the tanks. Because of the extreme length of the machine, a "U" shape design was established. To provide easy access to the work tanks, they were mounted to the inside of the "U" with the large reservoirs below.

With a minimum of five changes of solution per hour designed into the machine, it was felt advisable to do all heating and temperature control in the reservoir tank. Circulating pumps, filters, and solution heat controls were mounted on the outside of the "U" to provide easy access for maintenance. A system of chain driven sprockets was to be used to drive the tape through the machine from a tandem reel stand, mounted at the input leg of the "U", to another reel stand mounted at the output leg of the "U". Each reel stand also had provisions for reeling and playing out the filler strip. It was necessary to add this filler between coils of material to provide proper reeling and to keep the headers in adjacent layers from ensnaring and becoming bent.

About this time several subcontractors were contacted. They reviewed our developments in order to quote on the design and build portion of the machine. George L. Nankervis Company, Detroit, Michigan, was the only supplier of the five contacted willing to undertake the project.

In general, their finished design was very close to the sketches made during our development. One of the variations in their design was the substitution of magnetic wheels in place of the sprockets for driving and guiding the tape through the machine. The magnetic wheels used to guide the tape utilize the field of the magnets to hold the tape up against a guide piece for maintaining strip height.

The problem of strip feeding was greater than had been anticipated. It was found that the forces building up as the tape was drawn and twisted through the machine, increased to the extent that the .010-inch-thick steel strip parted on several occasions. The strip thickness was then changed to .015 inch. This increase is thickness appeared to be a solution to the problem; however, it was felt that the forces exerted on the strip had to be reduced to eliminate possibility of strip failure.

Since this problem resulted from our basic design, the machine was accepted and shipped to our plant so that additional work could be carried out on this problem.

V Operational Problems

After installing the machine and connecting the piping, electrical controls, and pressure bulbs for temperature recording, a full scale prove-in was started.

The largest and most time consuming problem was improving the tape drive mechanism. Various changes were made. Today this drive runs well with a .010-inch-thick strip. The magnetic guide rollers along the machine were replaced by free turning sprockets and a capture roller, which keeps the strip engaged with the sprocket. This modification eliminated an operating problem which became especially troublesome when ferrous matter collected on the magnetic rollers. The twisting or warping action required to clear the tank ends also provided quite a drag; by eliminating the twisting in all but the gold plating baths and converting to a horizontal feed with immersion rolls, much additional drag was eliminated. Another improvement in the tape drive was made at the corners of the "U". The strip originally turned the corners on idler pulleys; these idlers are now replaced by rollers driven by small motors so that the circumferential speed of these rollers is slightly higher than the tape speed. Now, if the tape is strained, tape pressure against the roller increases friction and the tape is driven similar to a belt; when strip pressure decreases, the roller slips inside the strip.

During the prove-in period some trouble was encountered with the small pumps used on some of the cleaning and recovery rinse station. These pumps were mounted horizontally. In this position they were hard to prime because an air lock formed in the cavity. The pumps were then mounted vertically. Now the air is removed as the pump is primed and the problem is eliminated.

The alarm system used with the water sprays also needed changing. A switch with a movable vane actuator was in the original design. After installation was completed and the system was tried, it was found that the flow of water through these switches was insufficient to energize them. Another type of flow meter was substituted; it monitors water flow and actuates the alarm system by sensing the pressure differential across an orifice.

As the first parts were plated, bare spots appeared between the leads. These spots were caused by a screening or shading action resulting from inadequate space between the leads. This was remedied by spreading and forming the leads before welding the tips on the Header Assembling Machines. The headers now have the leads spaced in such a manner that adequate free flow of plating ions is provided.

During the prove-in and shop trial runs, changes were made on piece parts. The length of lead was shortened necessitating a change in bath height; as a result, the standpipes of the tanks were modified to permit ready adjustment of solution levels in the tanks. Additional changes were also made in the plating process, elimination of copper plating and decrease in gold plate thickness as described in the development section. These changes also modified the operating cycle of the machine. With the decreased gold plate and the shorter lead length it was no longer practical to add more plating to the platform in a second plating bath thus the second plating bath was eliminated. The elimination of copper plating with accompanying changes in gold striking also meant that the copper plating bath and cyanide bath preceding it were no longer needed. In spite of these changes, it was very practical to run the machine as before, however, with the pumps and rectifiers for unused tanks turned "off".

The problem of plating TO-5 headers also was investigated. The larger diameter platform on these headers, with a resulting difference in area to be plated, required different plating currents. Headers plated with the new current settings established were satisfactory. The increased diameter of TO-5 headers also meant that a thicker filler material was needed and headers had to be welded to the strip on 1/2-inch centers. This reduces the capacity of the machine to just under 1000 units per hour for these headers. These were the only differences in plating TO-5 and the TO-18 headers.

Plating personnel readily adapted themselves to the mechanized operation during shop trial runs.

Maintenance during the shop trial consisted mostly of repairs caused by the corrosive action of the ambient air and the liquids used in the machine. This appeared as dirty contact points in relays, stiff bearings along the machine, and leaks from the piping and acid pump. On three occasions the temperature sensing system of the steam regulator failed and on each occasion it was found to be leakage of gas from the bulb. The pressure gages on the cyanide baths had soldered connections inside which were corroded by the solution. Replacement gages with monel movement and alloy welded tube connections have been substituted.

VI Machine Performance

Results during this shop trial period were very good. When the operation was in control, plating was perfect. Occasionally a part had to be discarded for imperfections existing from an earlier operation. At times, a relay in one of the plating rectifiers would not work properly and plating would go out of control. Another minor cause for rejections occurs when bath composition goes out of control; this happens when a chemical is not replaced as it is depleted and is an operator deficiency. A small percentage of parts was also lost when the strip did not track properly; some parts were badly bent whenever the strip left the rollers. The yield from the machine during this stage of operation was better than 98 percent.

VII Conclusion

The electrical system of the machine has given very little trouble and is simple enough that, except for precision relays in the rectifier control circuits, the average electrician can maintain it. Barring corrosive action, mechanical components of the machine also have performed excellently.

Additional work contemplated for Phase 2 of the Contract is the development of a quick method of evaluating the plated surface and the incorporation, into the machine, of a station for chemically surface polishing the header before plating. A method of evaluating the plated surface very soon after the header leaves a plating bath is very desirable. Corrections to the baths and controls can then be made soon after they are found necessary. Headers are presently being surface polished with a very brief acid dip before being attached to the strip. This process is not compatible with the Header Continuous Rack Plating Machine. If a suitable process is developed, this operation could be incorporated on the machine.

Since this machine replaced a batch plating process, which is a highly productive type of manufacture, gains in estimated output were not anticipated. It is felt, however, with a better grade header, the ratio of headers needed for bonding starts to finished transistors will be reduced with productive benefit the out-growth. Success in attaining the original goal has been realized. The new technique for holding the headers so that each part remains straight and see exactly the same conditions as it moves through the baths is definitely a great aid in making a straight uniformly plated header.

PLAN DIAGRAM OF HEADER CONTINUOUS RACK PLATING MACHINE

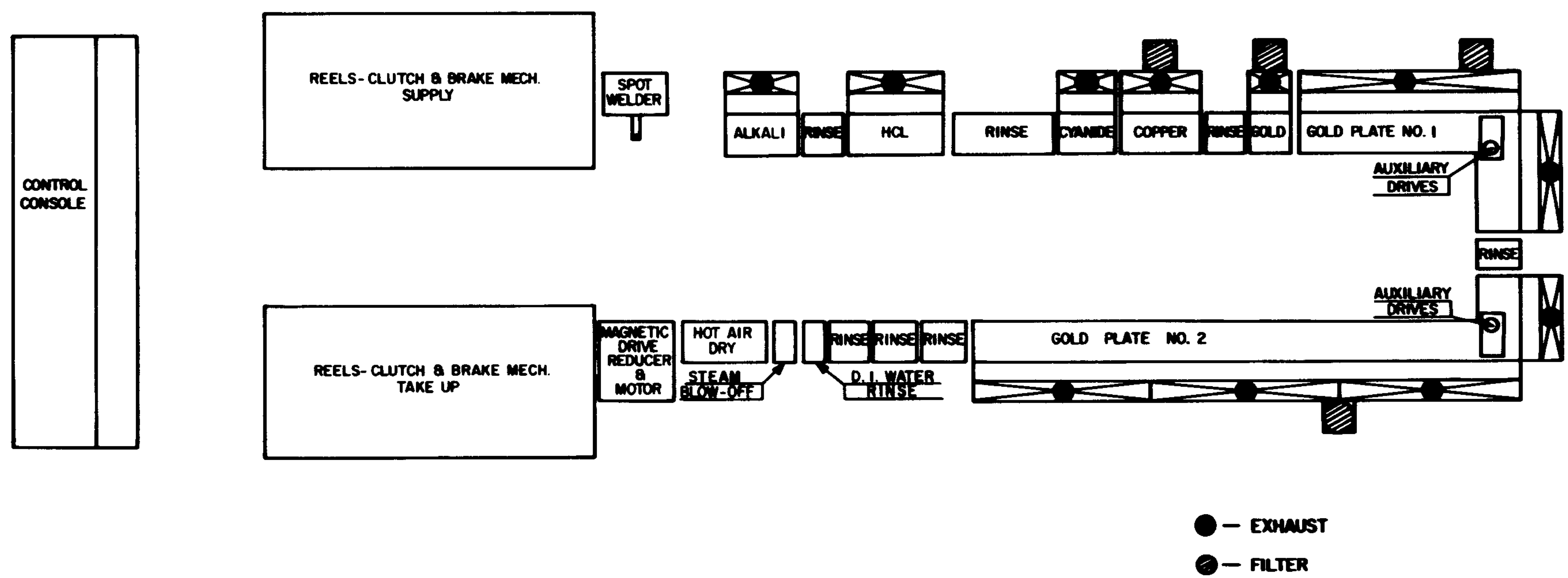
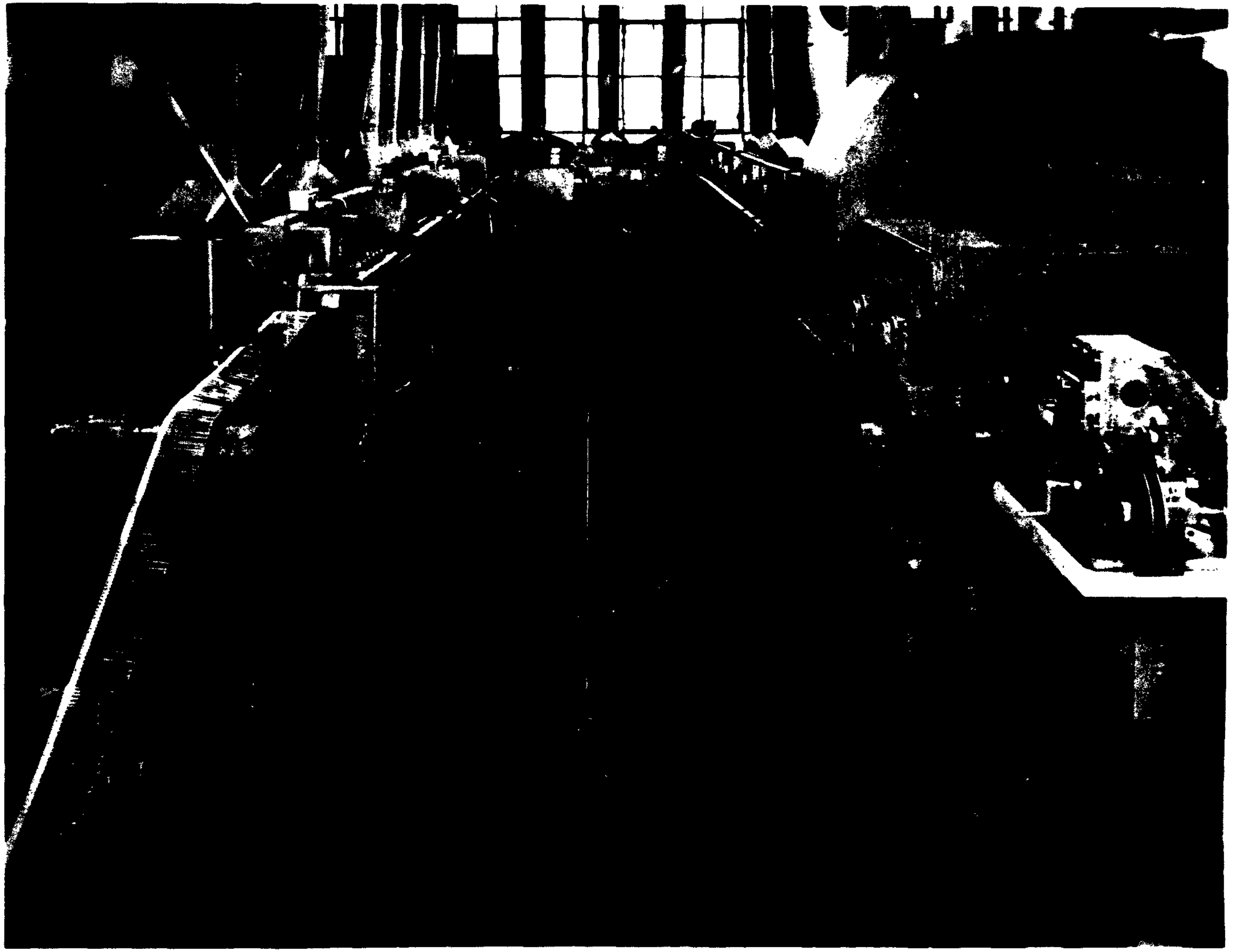
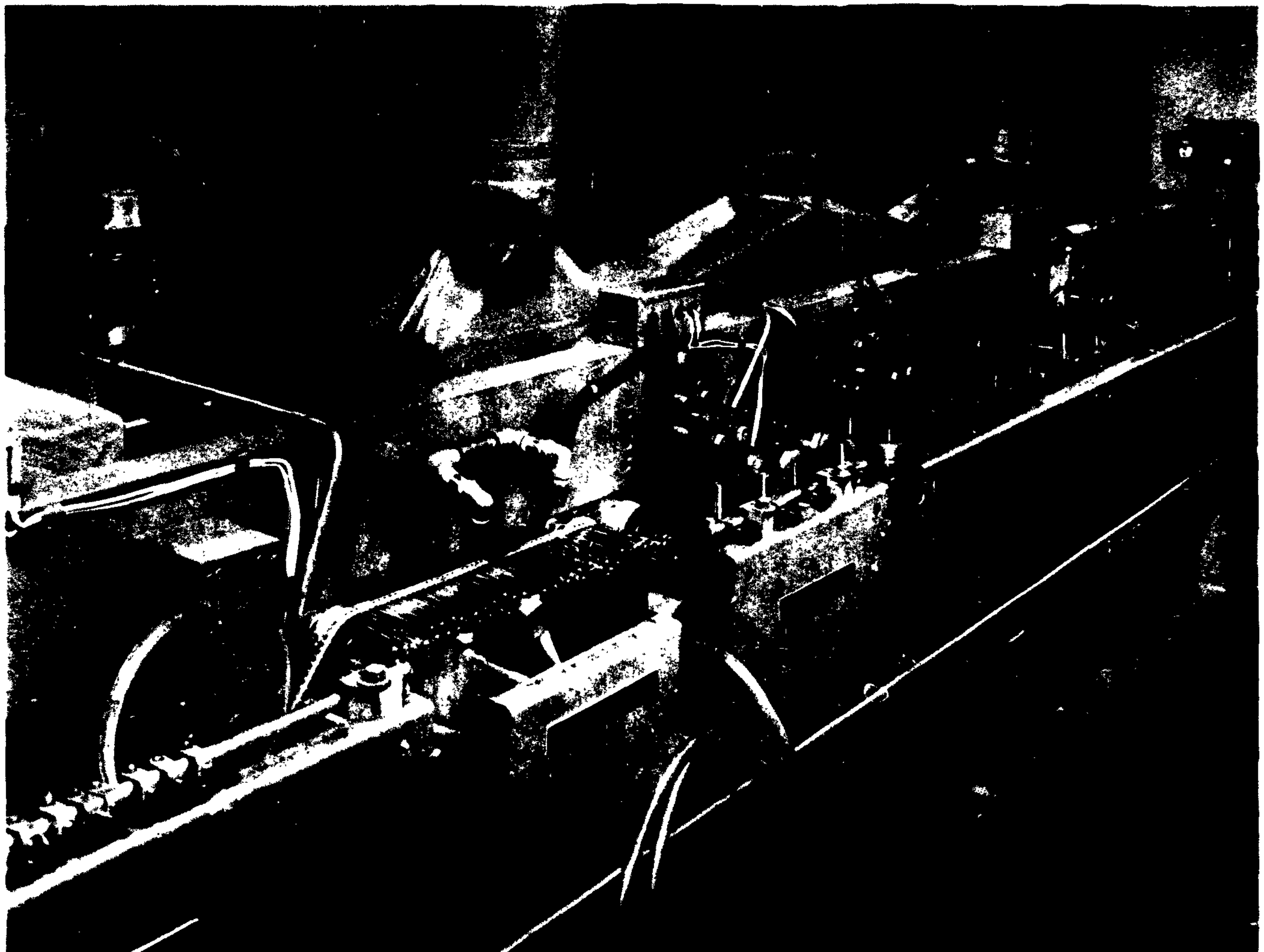


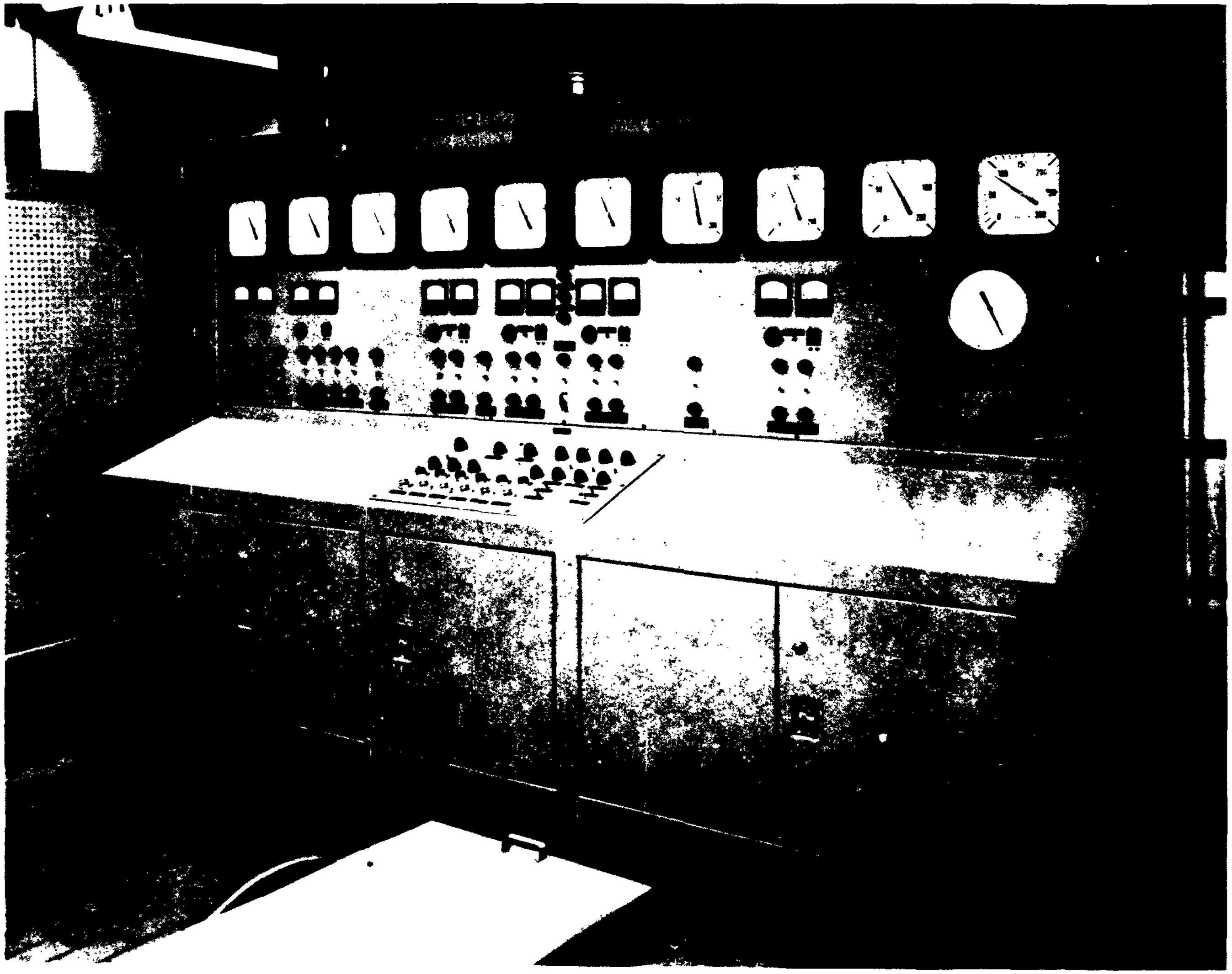
FIGURE 3.9-1



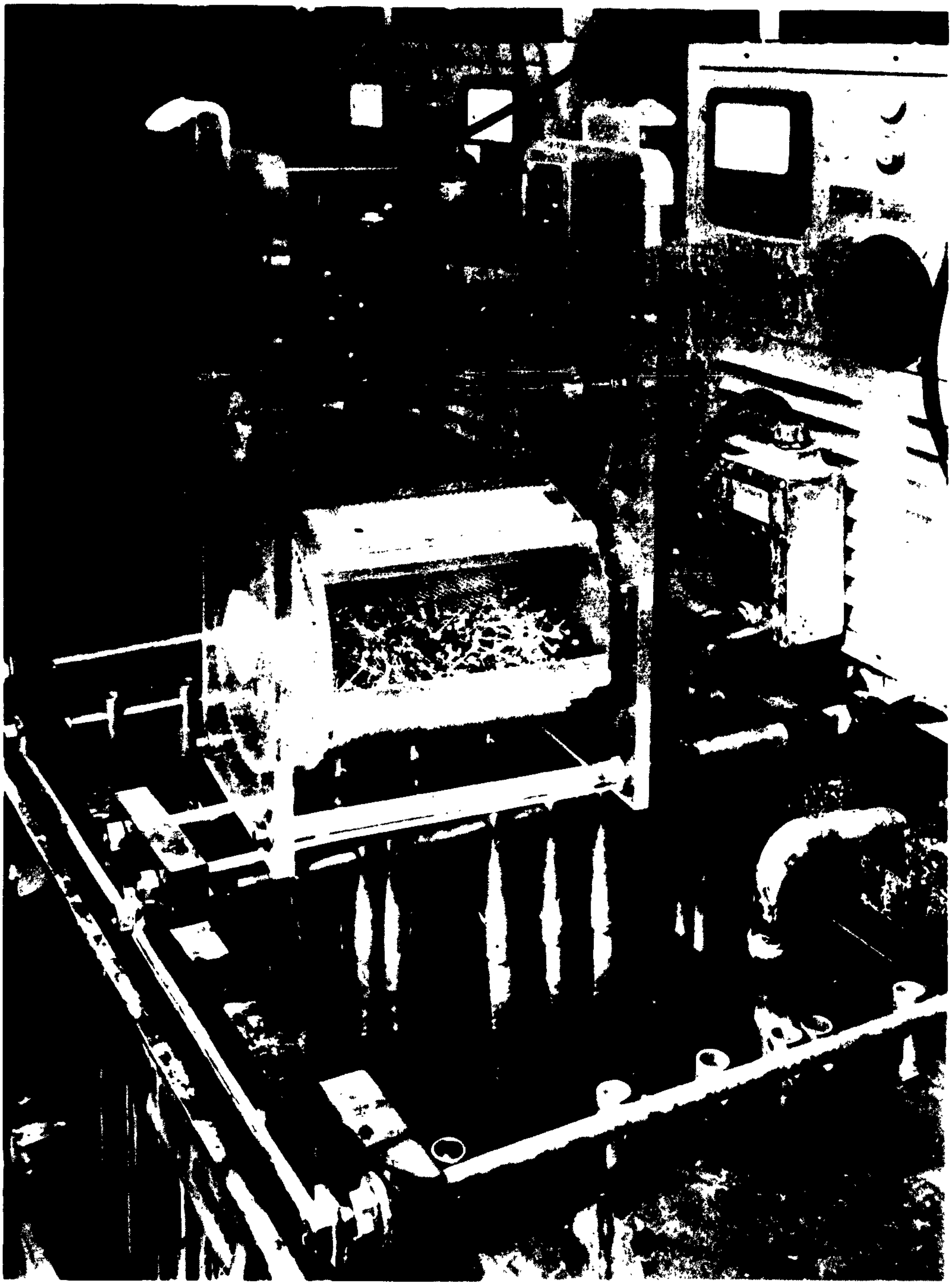
HEADER CONTINUOUS RACK PLATING MACHINE
FIGURE 3.9-2



STRIP WARPING ACTION ON HEADER CONTINUOUS RACK PLATING MACHINE
FIGURE 3.9-3



CONTROL CONSOLE OF HEADER CONTINUOUS RACK PLATING MACHINE
FIGURE 3.9-4



BARREL PLATED HEADERS
FIGURE 3.9-5

SECTION 3.10

CAN GETTER ASSEMBLING

R. W. Ingham

CAN GETTER ASSEMBLING

I General

Fabrication of a moisture seeking non-tabulated can is accomplished on a straight-line Can Getter Assembling Machine. This machine is actually composed of three separate machine frames. The first or Can Loading Section (Figure 3.10-1) receives precleaned and degreased non-tubulated TO-18 cans and feeds, orients and loads these cans into pallets that will act as a holding device for the furnace treatment and later as a storage device while the parts await further processing. The pallets are manually loaded into a rack by the operator and are removed mechanically as required by the machine. The pallets are indexed along a track and at successive stations cans are loaded into the holes or nests, filled with measured amounts of finely ground pure nickel, and later placed in magazines (Figure 3.10-2) for transportation to a controlled atmosphere moving hearth sintering furnace. This furnace, which is associated with and a vital part of the process, is not considered to be part of the Can Getter Assembling Machine, nor will it be covered in this report.

The second section which is known as Powder Leveler and Furnace Loading Section (Figure 3.10-3) receives the loaded magazine from the Can Loading Section. The pallets (Figure 3.10-2) are unloaded one at a time from the bottom of the magazine and guided by a track to the leveling station. After leveling, the pallet is placed on the furnace's moving hearth. A timer controls the rate at which pallets will be fed and should be set so as to allow a 1/4-inch space between pallets after they are on the hearth. This machine will handle cans for both TO-18 and TO-5 devices.

The third section of the machine or Getter Loading Section (Figure 3.10-5), receives the pallets as they emerge from the sintering furnace previously mentioned. The nickel powder has now been fused to the can and to itself forming a metal sponge that is firmly attached to the can. At the present time the pallets will be manually loaded into magazines and transported to the Getter Loading Section where the pallets will again be removed mechanically from the magazine one at a time. This section of the machine is also of the in-line type. Pallets are indexed from one station to another by an air powered indexing mechanism. After being removed from the magazine, the pallet and its contents are clamped in a fixture, inverted, vibrated to remove any material not firmly attached, returned to the track, filled with a measured amount of barium hydroxide, heated to melt the barium hydroxide and loaded into an identical magazine for transportation to a controlled atmosphere moving hearth activating furnace similar to the one used for sintering. This furnace, like the one previously mentioned, will not be covered in this report. The basic or original purpose of the machine was to provide a mechanized method of fabricating gettered cans of a quality that would satisfy the Nike Zeus Contract and, at the same time, permit the manufacture of the large number of devices required.

Since the actual machine, as covered by Contract No. DA-36-039-SC-72729, is really three separate machines, each handling separate and individual operations; the description, development, operation and conclusion portions will be handled separately. Each will be complete within itself. The group will then be tied in by an overall evaluation or summary relating original intent and the degree to which the final machine satisfies this intent. The various sections of the machine will be handled in the order of their use in the process: The Can Loading Section, the Powder Leveler and Furnace Loading Section, and finally the Getter Loading Section.

CAN LOADING SECTION

II Description

The Can Loading Section is an in-line machine approximately 8 feet long by 2-1/2 feet wide. The machine is built around a box-type frame having a floor to table height of 3 feet. A 3/4-inch-thick aluminum jig plate serves as a mounting surface for the stations which feed and orient the cans, convey these cans to the loading or inserting station, stack and feed pallets, measure and deposit nickel powder into the cans, and restack or load the pallets (each pallet holds 112 cans) into magazines at a rate of 8,000 cans per hour.

Feeding and orientation of the precleaned cans is handled by a Model EB-01-C Syntron Electric Parts Feeder fitted with a 14-inch stainless steel cascade-type bowl (Item 1, Figure 3.10-1). This bowl which serves to orient and feed the cans also serves as a reservoir or magazine and has the capacity for 1-1/2-hours running time. The bowl has eight discharge openings each of which is matched or mated with a track in a stainless steel chute (Item 2, Figure 3.10-1). This chute conveys the cans via gravity to the loading or can insertion station (Item 3, Figure 3.10-1). The empty pallets are loaded into a magazine which also serves as the support for the stainless steel chute. This magazine holds 30 pallets which is sufficient for about 20 minutes of operation. The machine is suitably interlocked so that when the pallets in the magazine fall below a predetermined level, the machine will stop cycling. The can insertion station is unique in that lowering the inserting frame opens the escapement, prevents feeding more than one row of cans at a time, and moves all other cans back about 1/32 inch to prevent overlapping of can flanges. The inserting or guide pins have been drilled so that dry filtered air can be blown through them to overcome static and/or magnetic charges that might cause the cans to cling to the guide pins while they are being withdrawn.

Indexing of the pallets, one row at a time, is done by an air - powered device that imparts a rectangular motion to the index pins. The pins engage the next row of holes to be filled and moves them to a position directly below the can loading station before being lowered out of the way.

The pallets continue to move, one row of holes at a time, until they reach a predetermined position under the powder load station (Item 4, Figure 3.10-1). When a pallet has moved into position under the guide plate of this station, a shutter is indexed so that the measuring cavities are directly above the cans. A vibrator is then energized to insure that all of the powder previously measured is dropped into the cans loading an entire pallet of 112 cans at one time. The amount of powder entering the cans is determined on a volume basis. The shutter or measuring plate, having 112 holes spaced on the same centers as the holes in the pallets, is re-filled with nickel powder while the next pallet moves into position.

From the powder loading station the pallets are moved to the pallet loading station where they are stacked in the magazine. Loading is from the bottom with the motion being derived from a hydraulically controlled air cylinder located directly below the aluminum mounting plate. The magazine loading mechanism lifts the pallet from the track, trips a set of weighted fingers, and then lowers those pallets in the magazine onto the fingers. The machine is interlocked so that the air operated lifting plate must have completely returned to its lowest position before another pallet can be fed from the pallet storage magazine located under the 8-track chute (Item 2, Figure 3.10-1).

In addition to the physical dimensions given at the beginning of this section, it might be added that the machine operates from a 440-volt, 60-cycle, 3-phase power supply and requires about 2 kilowatts of power. Air requirements are approximately 4 cubic feet per hour at a line pressure of 85 pounds per square inch gauge.

III Development

The original feasibility studies were conducted with the idea of using vycor discs as the moisture getting agent. Various spring-type clips or holders were tried, discarded and even tried again using different conditions and/or materials. The one, in our opinion, that seemed to hold the most promise was what came to be called the "nailhead". The "nailhead" was formed by cold upsetting nickel wire. For this method the vycor disc was placed in the cans and the "nailhead" was inserted with the head acting as a restrainer and the stem was resistance welded to the can. These units were centrifuge tested to 20,000 gravities with no visible or measurable deterioration.

The use of vycor was phased-out and all further development work stopped when experimental work indicated that a more effective getter could be fabricated using a nickel sponge saturated with a slurry of barium and strontium carbonate. This presented a whole new set of conditions, so development work was started to determine the feasibility of mechanically assembling a saturated nickel sponge pellet. About July 1960, the development had progressed to the point that preliminary design could be started. Formal design of a mechanized can-getter assembly machine was started late in 1960. An artist's conception is shown in Figure 3.10-8.

This machine was designed to feed and orient nickel pellets saturated with the getter material having gold evaporated on one side. The machine was to place this pellet and a thin copper brazing disc in each can. The can, brazing disc, and pellet were then to be loaded into pallets for furnace brazing and activation. The design was completed about July 1961 and construction was started immediately.

About this time the development program indicated that a more reliable, less expensive process involving less labor and allowing for higher volume production was possible. The process that evolved is basically the one used to date and resulted in the construction of the machine covered by this report. The process consisted of forming a nickel sponge by sintering finely ground nickel powder to the can and to itself to form a sponge or porous mass. At this time the method of introducing the gettering material had not been definitely decided. Preliminary design work was started. It was at this time the decision to build the machine in two parts was made. Late in 1961 formal design was started and progressed satisfactorily. Several small mock-ups were built to prove feasibility. The can feeding device that had worked well in mock-ups did not function with the reliability considered essential; therefore, the can feeder was redesigned or reworked several times before it would function with any regularity. Modifications to the pallets were also made to improve the repeatability of the can loading motion.

The powder load station consists of a fixed funnel plate which also serves as the bottom of the hopper, a measuring plate which also acts as a shutter, and a guide plate which also serves as the guide or locator for the measuring plate. Originally, the measuring plate was to be indexed by a solenoid having a 12-pound pull. Early work with mock-ups indicated that 8 pounds would do the job. Actual practice, however, indicated that upwards of 20 pounds would be required. A one-inch bore air cylinder was substituted and found to work satisfactorily.

IV Operating Problems

When the machine was put into limited operation by the engineers using new pallets, the machine performed reasonably well. After the pallets had been through the furnace several times, the performance deteriorated to the point that the can loading station required almost constant attention. The can loading station was modified to insure better location and insertion of the cans. The pallets were returned to the shop for checking and possible reworking.

After the pallets were returned, the machine was again operated by the engineers. At first, the machine operated very well, but after the pallets had been through the furnace several times, the old problems of jams and/or misfeed returned. The index mechanism was checked, and the diamond-shaped pins were found to be bent. New, heavier and stronger pins were installed.

The pallet indexing mechanism, as originally designed, was spring driven with a positive return. This was done to prevent serious damage to parts and/or machine in the event of a jammed can or other malfunction. The spring, which was under an average compressive force of about 60 pounds, had to be reset at regular intervals to overcome normal "set".

To overcome this tendency of the spring to distort and still not have a positive movement, the activating force was changed from a cam to two 1/2-inch double acting air cylinders with flow control on the exhausts. The spring mentioned earlier was removed. This change made it much easier to remove and correct a jam caused by an erratic index or poor can location. Maintenance time per jam was reduced from about 10 minutes to about 1-1/2 minutes.

V Conclusion

The Can Loading Section of the Can Getter Machine has demonstrated that it can feed, orient and load cans into pallets and insert measured amounts of nickel powder into these cans at the rate of over 8,000 TO-18 cans per hour. The quality and uniformity of the cans were equal to or better than on the manual line.

POWDER LEVELER AND FURNACE LOADING SECTION

VI Description

The Powder Leveler and Furnace Loading Section (Figure 3.10-3) is an in-line machine approximately 4 feet in length and 2 feet in width. The machine is built around a box-type frame having a floor to table height of 2-1/2 feet. This frame is capped with a 3/4-inch-thick aluminum jig plate on which all equipment is mounted. An index motion is provided by electrically controlled double acting air cylinders. Speed control of the index motion is via flow control of the cylinder exhaust.

The pallets are moved from the magazine to the moving hearth of the furnace in three indexes. The pallets are fed from the magazine by removing the bottom pallet while the balance of them are supported on fingers (Item 1, Figure 3.10-4). When the pallet is indexed from the magazine it is moved to the leveling station (Figure 3.10-3) where a timer controlled electric bin vibrator levels the powder. The pallet moves via a track to an idle station, the only purpose of which was to permit the use of a shorter stroke air cylinder and, thereby, reduce the length of the machine. The next index moves the pallet onto the moving hearth of the furnace.

A timer (Item 2, Figure 3.10-4), located on the back panel of the machine, controls the frequency of the index motion. This timer can be varied from 15 seconds to 6 minutes. A second timer (Item 3, Figure 3.10-4) controls the length of time the pallet is vibrated. The only requirement for setting these timers is that the cycle time for indexing be longer than the cycle time of the vibrator.

VII Development

The great difference in the operating speeds of the can loading portion of the machine and the sintering furnace prompted the consideration of a mechanized furnace loading device. Since the principle drawback to the manual handling of the sintered powder method of getter preparation was the dependence upon careful handling by the operator, it was only logical to combine the leveling and loading operations. The pallet feeding device being designed for the getter loading portion of the machine was adapted since the operations to be performed were identical. Prior experience with linear vibrators suggested that this might be a suitable mechanism for leveling of the fine nickel powder. A mock-up was made and given a trial in the production shops. This mock-up served until the machine was built and is still used for small runs on occasions.

VIII Operating Problems

The machine was installed and operated the same day. During use, several minor problems developed all of which have been eliminated or brought under control by regular maintenance. The magazines originally designed for 25 to 30 pallets could not be easily handled by the operators, so they were reduced in capacity and redesigned so that they would hold a maximum of 15 pallets. Since the leveler and loader handles pallets that have been manually loaded, in addition to those that have been machine loaded, the machine requires vacuum cleaning of the tracks once each week to remove nickel powder vibrated off the sides and bottom of the manually loaded pallets.

IX Conclusion

The machine has demonstrated that it can satisfactorily level the powder in the cans and load the furnace more uniformly and reliably than operators can perform the operation manually.

GETTER LOADING SECTION

X Description

The Getter Loading Section of the machine is an in-line type in which pallets are moved from station to station by an air cylinder (Item 1, Figure 3.10-6) which operates a pawl-type index. The pallets are guided by the track visible on Figure 3.10-5. The machine is approximately 8 feet long by 2-1/2 feet wide. The frame of the welded box-type construction has a floor-to-work-table height of 3 feet. The 3/4-inch aluminum jig plate which covers most of the table top is used as a mounting medium for the various stations; hydraulically controlled air motors are located on the underside.

All motions on the machine are air powered, electrically controlled, and suitably interlocked so that each operation must have been completed or have progressed to a predetermined state of completion before a related motion is initiated. The machine mechanically unloads pallets from a magazine, moves them to the shake-out station where the pallets containing sintered cans are clamped to a section of track by an air operated plate. The station rotates 180 degrees and vibrates to remove any loose nickel powder from the cans, if any is present. Then it returns to the feed track and the pallet indexes to the getter loading station. This loading station is like the nickel powder loading station described earlier. It adds identical amounts of getter, barium hydroxide, to each can in a pallet whenever a pallet indexes into position under the hopper.

At the next station, the heating station, can-getter assembling is completed. The barium hydroxide is melted and attached to the nickel sponge by heating the bottom of the can. The pallet remains relatively cool and can be handled safely with bare hands. The heat sink of this station is maintained at $140 - 1^{\circ}C$ by four cartridge heaters. One hundred twelve cylindrical projection are machined into the top of the heat sink (see the heat sink to the left of the magazine in the foreground of Figure 3.10-5). On signal from the machine the heat sink rises and the projections enter the holes of pallets previously indexed into position. After the projections contact and heat the bottoms of the cans, the melted barium hydroxide enters the porous sponge. After completing the heating cycle, pallets are indexed into a magazine for storage and/or transportation to the activating furnace.

The machine is equipped for either automatic or manual operation.

All controls are at eye level and within easy reach of the operator. The shake-out station was completely enclosed in plexiglas because of the hazardous operating requirements.

XI Development

The development of this portion of the machine parallels the development of the process. The intent and purpose of the sintered-powder-barium-hydroxide process was to provide a moisture getter of suitable capacity and ruggedness to match requirements of the Nike Zeus Program and, at the same time, be capable of producing the high number of devices required. In the development of the process, mock-ups of the loading and melting methods were built and proved-in. The information obtained from the use of these mock-ups was incorporated into the design of the machine.

The principle difference between the experimental method and the mechanized version is the adoption of a high frequency of impact instead of high amplitude and relatively low frequency impacts to remove loose particles from the cans. Early sudies indicated that both methods resulted in devices that met the requirements of the TO-18 and TO-5 type Nike Zeus devices. The shake-out station, as the particle removing mechanism came to be known, required that the pallet containing 112 cans with approximately a 1/32-inch layer of nickel powder fused inside had to be turned upside down (open side down) and vibrated to remove any particle that had not become securely fastened. Rotary air motors were purchased to provide the "flip-over" or 180 degree rotation because of their apparent simplicity and safety.

Due to the off-center nature of the load, control of these motors was not sufficient and the required operator safety was not obtained.

Hydraulic cylinders were installed on eccentrics to act as snubbers and provide some degree of speed control. Space limitations prevented the use of sufficiently large oil cylinders so the station was redesigned so that linear air motors (Item 2, Figure 3.10-6) with hydraulic speed controls could be used. The linear motion was changed to a rotary one by the use of a rack and pinion arrangement. Suitable covers and guards were installed to insure operator safety.

The design of the heating unit was done almost entirely by theory. Heat losses were calculated using published heat transfer coefficients. A Fenwall Proportioning Type Indicating Controller with a matched thermistor probe was chosen on the basis of advertising claims of $-1^{\circ}C$ sensitivity in the $140^{\circ}C$ range.

Cartridge heaters were chosen because of dependability, availability, and compact size. Four heaters were chosen to better distribute the heat and keep the temperature gradient within the heat sink below $2^{\circ}C$ in the area being used. Actual checks on the surface of the heated sink, using a thermocouple, indicated the total temperature variation to be slightly over $3^{\circ}C$. In order to provide a means of checking for heater burn out, a checking circuit was designed to permit reading the current drain of each heater while in use. This circuit was necessary since we chose to monitor the heat sink at only one point for temperature control.

Of particular note is the electrical control circuit which permits both manual and automatic operation. When the machine is operated manually, all safetys and interlocks remain in effect so that no damage to the piece parts or machine will be caused by attempting to operate stations out of sequence.

XII Operation

The machine was installed and leveled with no unusual problems. After the machine had been operated for several days, it was found that if the machine cycle were stopped during the powder loading motion, a second load of powder would be placed in the cans. A circuit to prevent this was installed on the machine and suitably labeled. No problems were encountered with the mechanical motions of the machine, but we did experience a variation in the amount of powder placed in the cans. A sieve having a mesh size of USS#20 was installed in the hopper to screen out oversize particles. This action corrected the condition, and no further problems have been encountered.

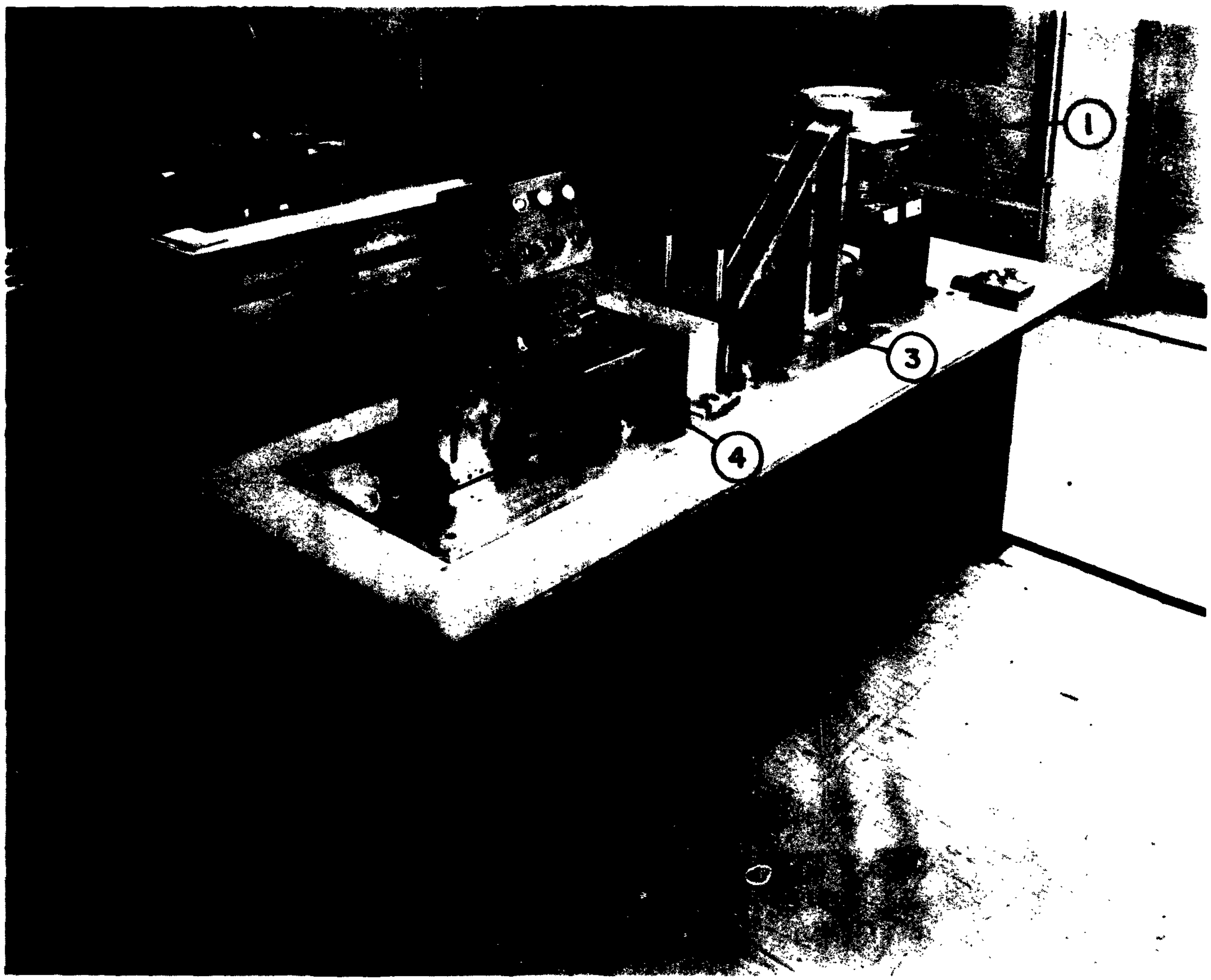
XIII Conclusion

The Getter Loading Section of the Can Getter Machine had demonstrated that it can provide gettered non-tubulated cans of a quality and uniformity beyond that obtained by manual methods. Because the barium hydroxide is stored and handled in a closed hopper, less material is lost or wasted. Presently, the machine is set to handle one pallet of 112 cans every 48 seconds; this time can be reduced to 40 seconds if higher production is required and the increased production can be handled by the activating furnace.

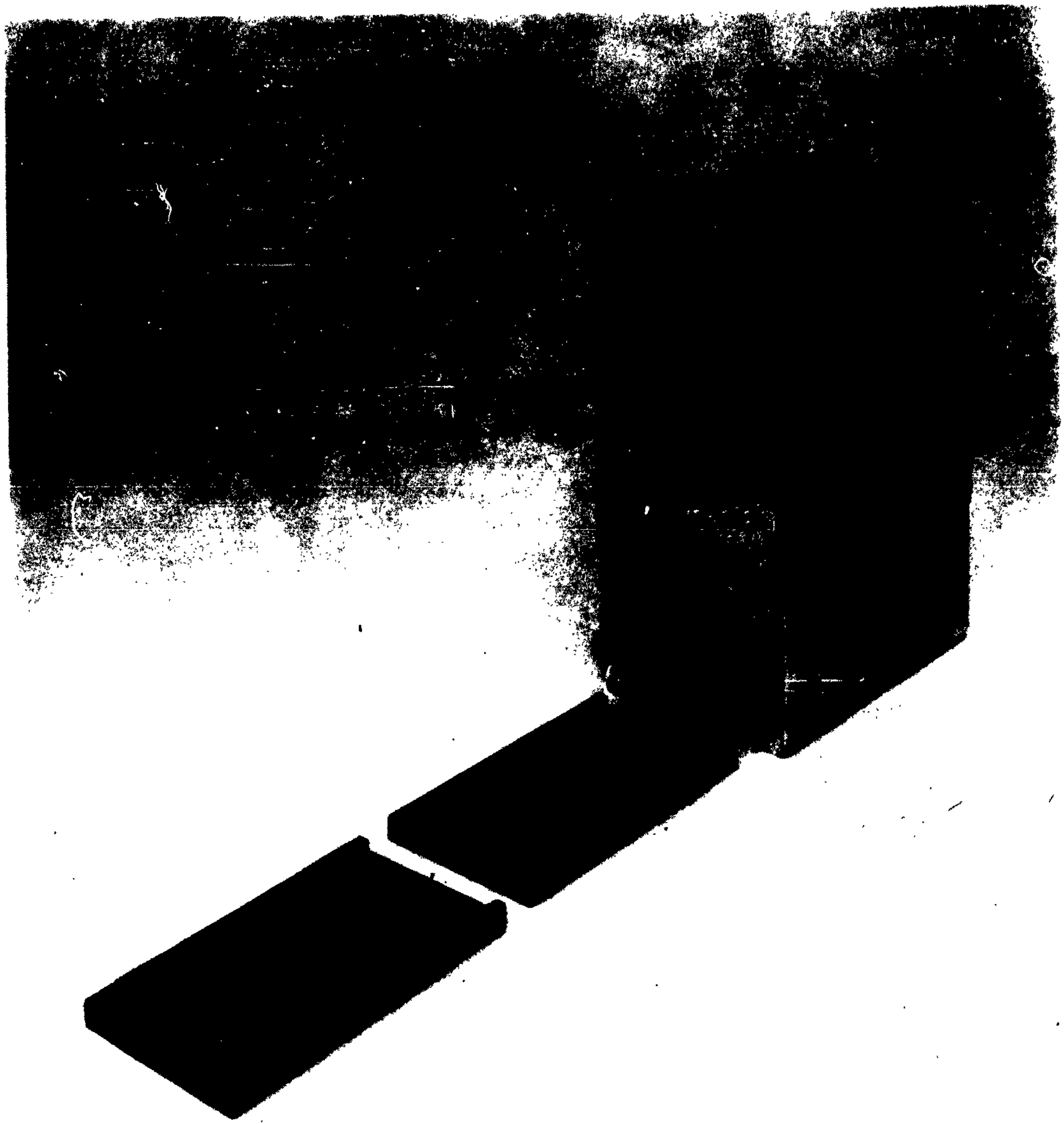
With this equipment, the activating furnace can be used more efficiently and a higher production can be obtained from the equipment now in use.

XIV Summary

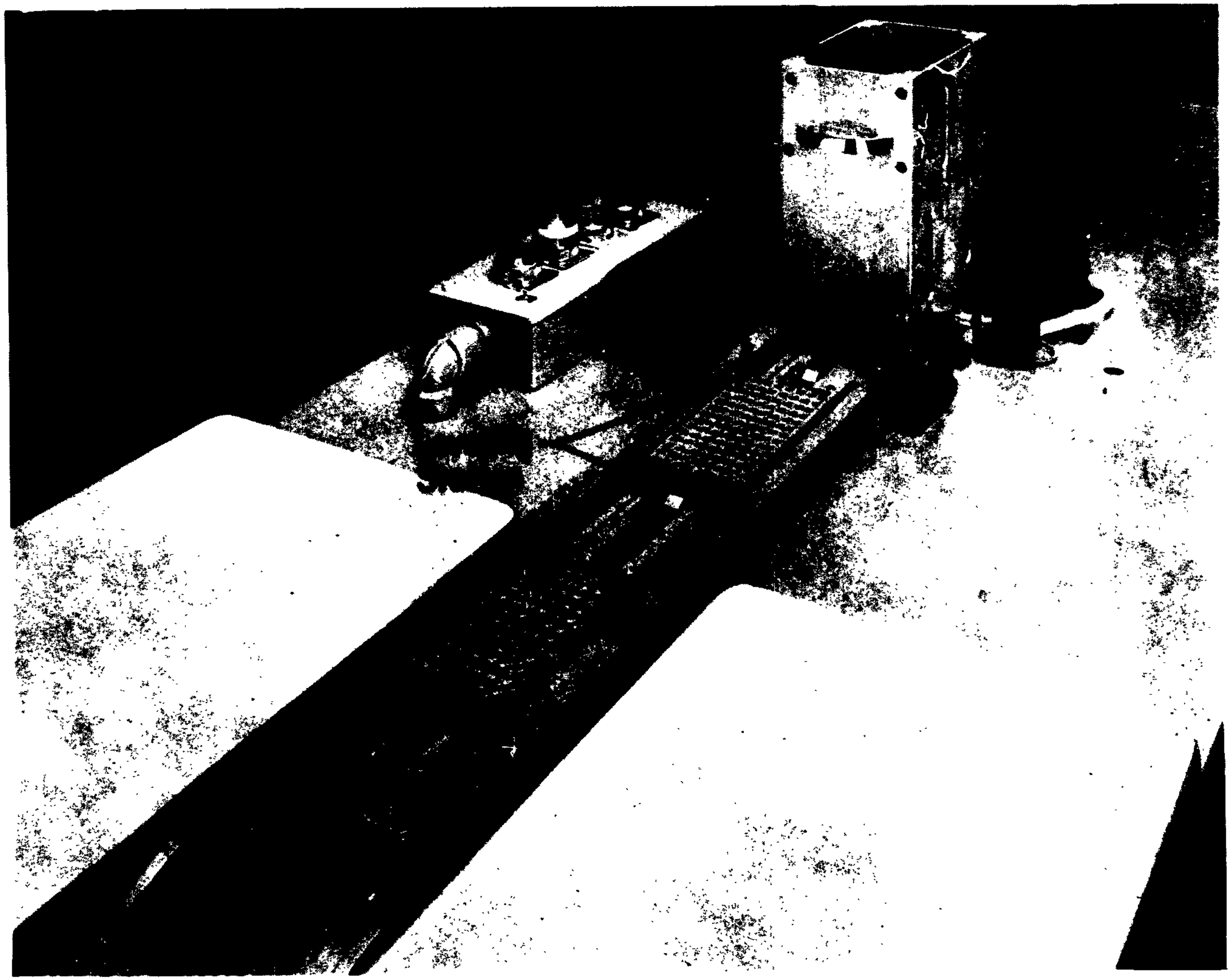
The Can Getter Assembling Machine, as designed and built and later modified, has demonstrated that it is capable of producing high quality non-tutulated closure cans for TO-18 semiconductor devices. The machine was built specifically for the high reliability device requirements of the Nike Zeus Program. The Can Gettering installation of which the machine is a part allows for the production of the large number of devices required with a minimum of floor space and operator attention. The complete installation permits manual production to be intermixed with mechanized production. The flow diagram of the pallet (Figure 3.10-7) shows the path and relative locations of the machines and related equipment.



CAN LOADING SECTION OF TO-18 CAN GETTER
ASSEMBLING MACHINE
FIGURE 3.10-1

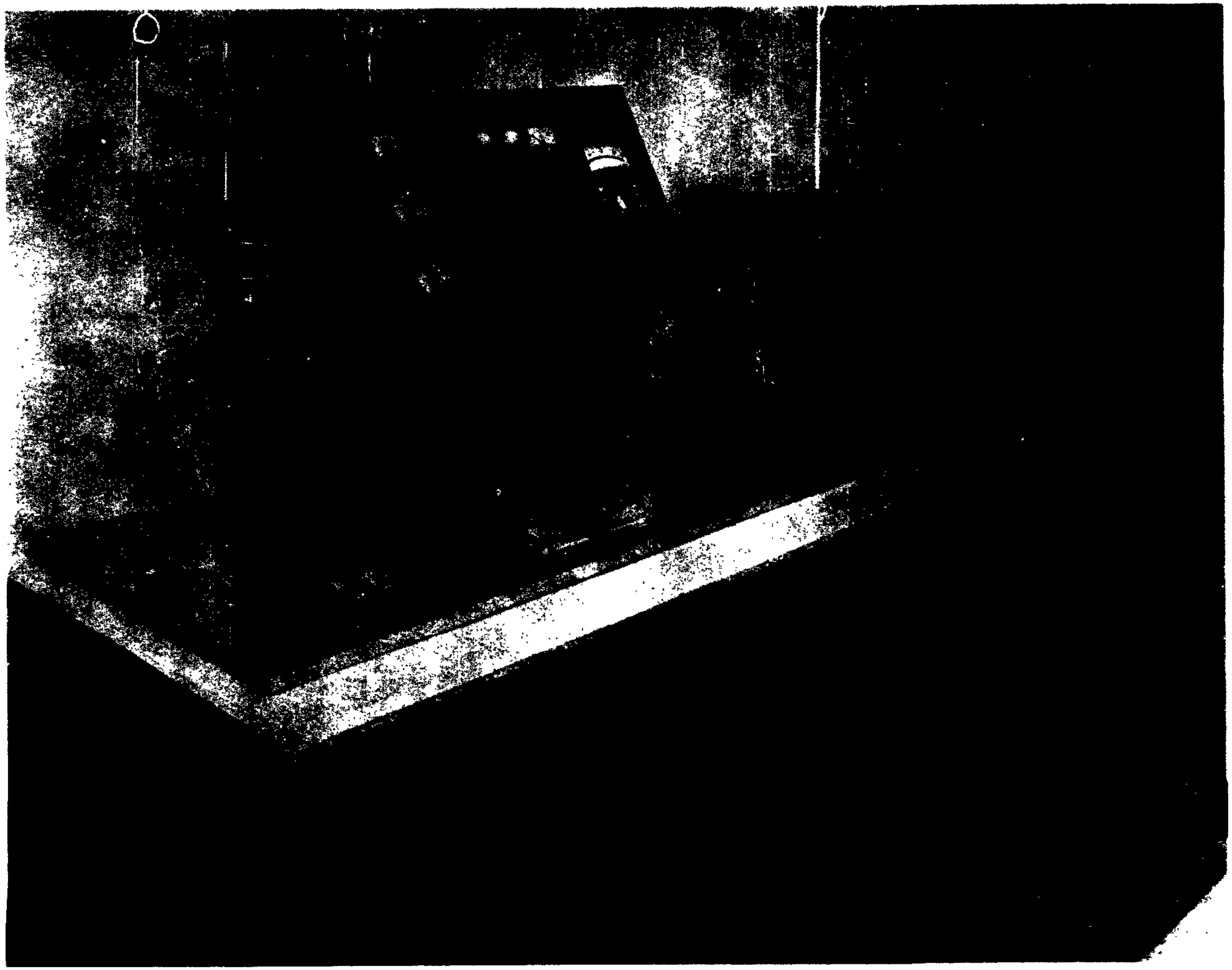


MAGAZINES AND PALLETS FOR
TO-18 CAN GETTER ASSEMBLING MACHINE
FIGURE 3.10-2

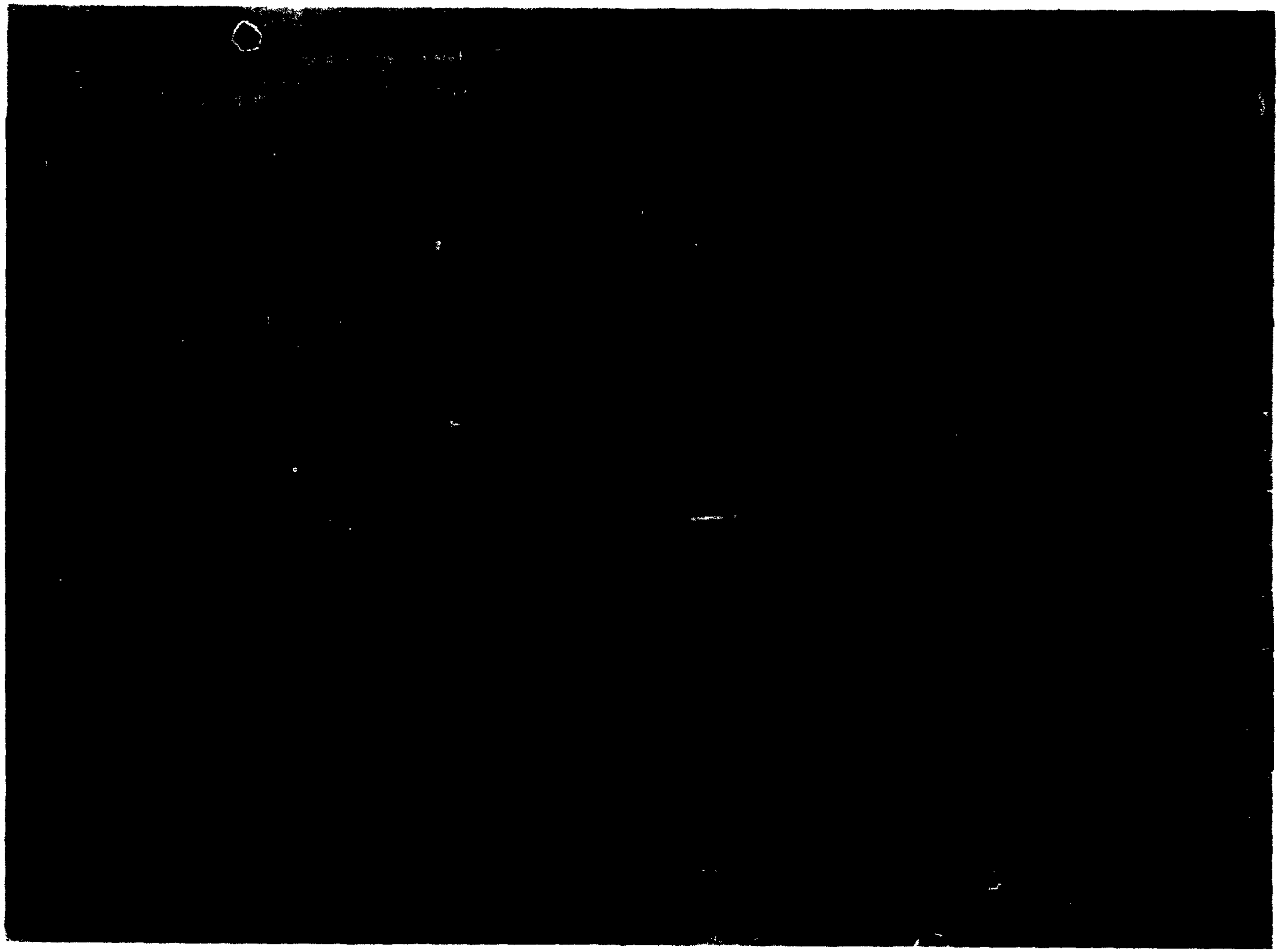


POWDER LEVELER AND FURNACE LOADING SECTION OF
CAN GETTER ASSEMBLING MACHINE VIEWED FROM FURNACE
FIGURE 3.10-3

OVERALL VIEW OF POWDER LEVELER AND FURNACE LOADING SECTION ATTACHED TO SINTERING FURNACE.
FIGURE 3.10-4



GETTER LOADING SECTION OF
TO-18 CAN GETTER ASSEMBLING MACHINE
FIGURE 3.10-5



INTERIOR OF GETTER LOADING SECTION OF
TO-18 CAN GETTER ASSEMBLING MACHINE
FIGURE 3.10-6

PALLET FLOW DURING CAN GETTER ASSEMBLING

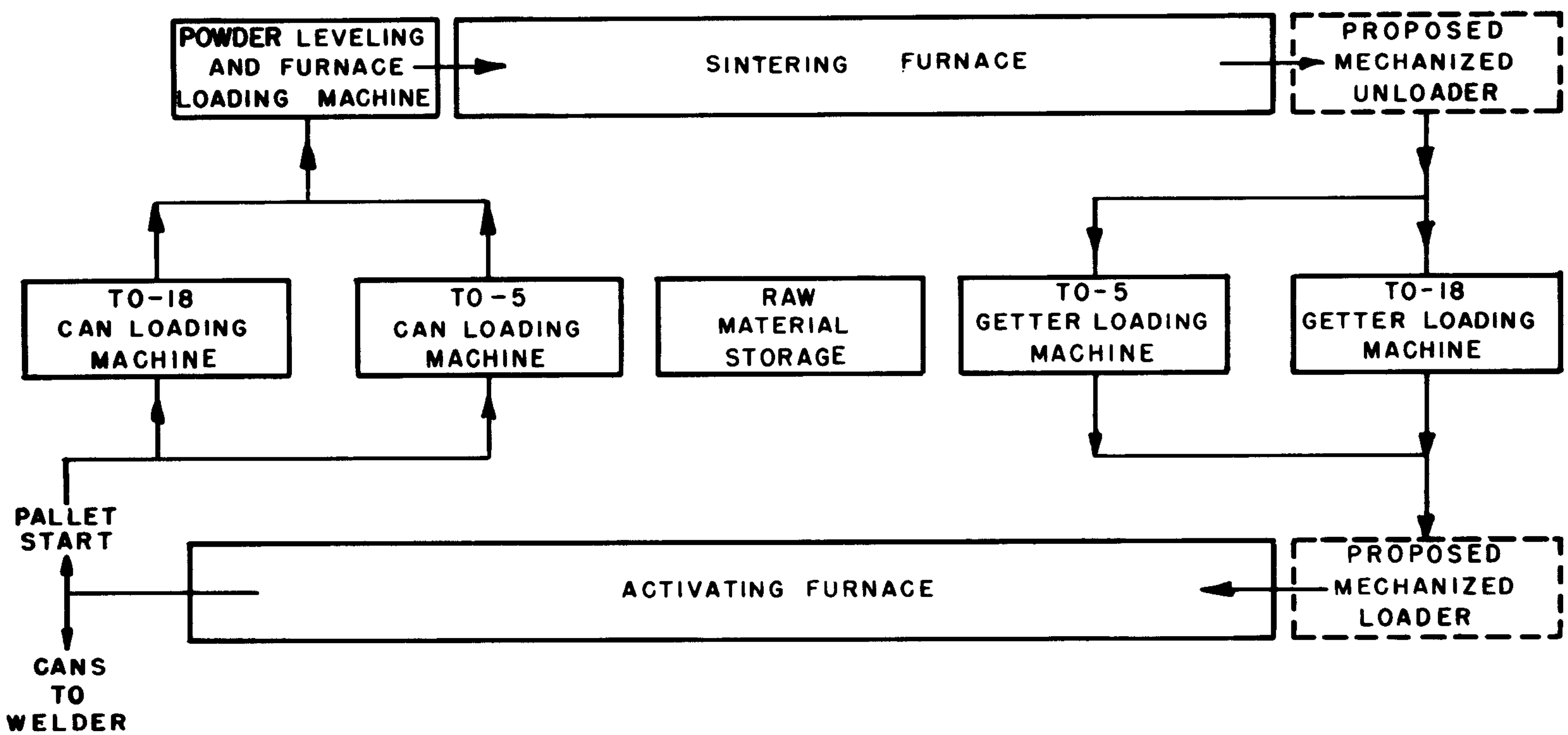
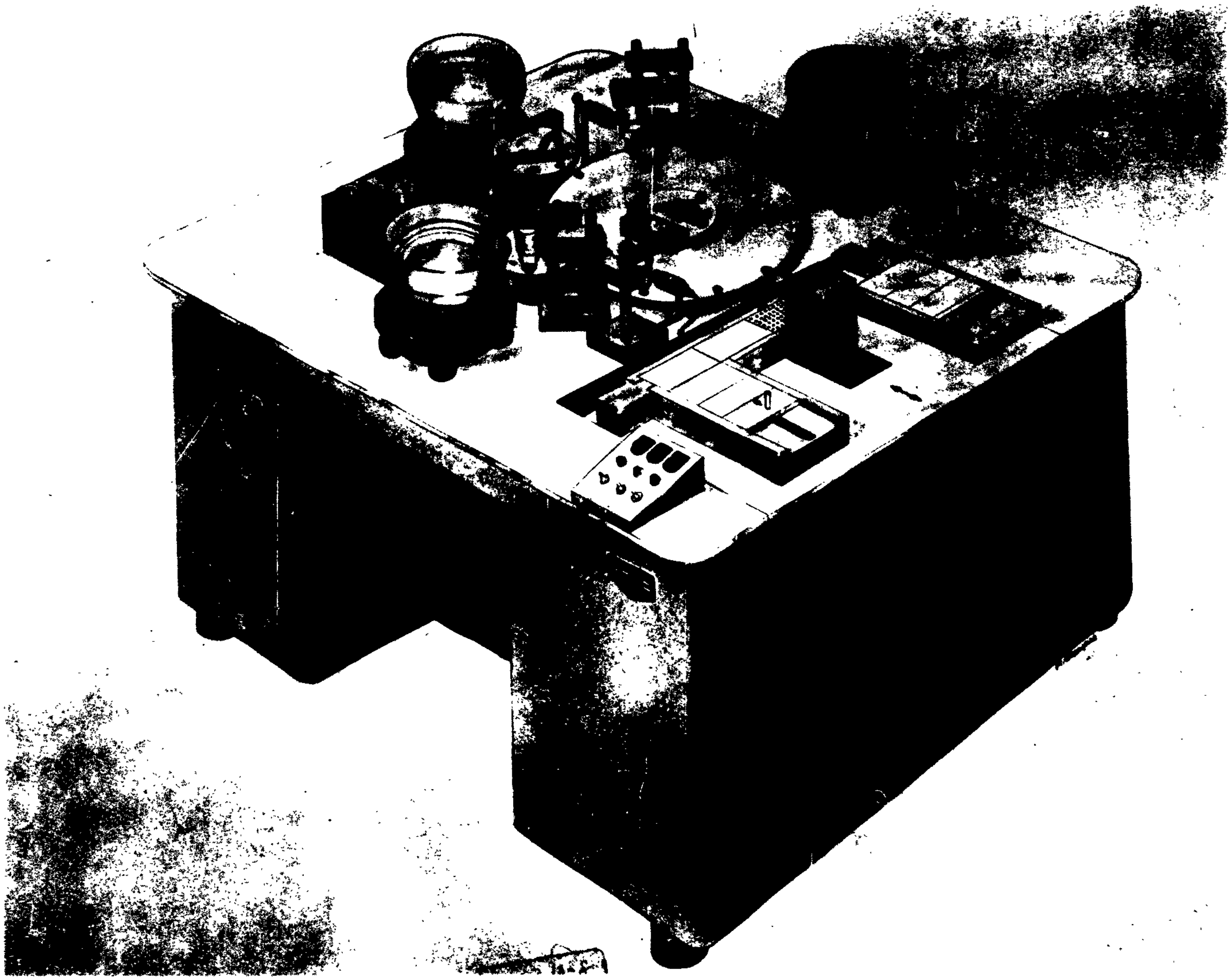


FIGURE 3.10-7



ARTISTS'S CONCEPT OF CAN GETTER MACHINE - JULY 1960
FIGURE 3.10-8

SECTION 3.11

SLICE SCRIBING

H. K. Naumann

SLICE SCRIBING

I General

The 2N559 Slice Scribing Machine was built to mechanize manual scribing operations, to reliably maintain specified wafer tolerances, to improve wafer breaking through improved scribing, and to increase operator productivity. This machine can scribe on .020, .030, .040 or .050-inch centers and can maintain an accuracy of ±.0002 inch.

A need for this machine was emphasized by the contemplated high volume Nike Zeus production requirements and the specific scribing requirements of the Wafer Breaking, Screening and Loading Machine. Development of this machine was brought to early and successful conclusion. Similar machines have been built for the 2N560, 2N1051, and 2N1195 transistor codes under Contract No. DA-36-039-SC-81294.

II Machine Description

The Slice Scribing Machine consists of four major assemblies. They are: (1) an indexing and locating mechanism (Assembly A, Figure 3.11-2) which provides the desired indexing and locating; (2) a scribing mechanism (Assembly B, Figure 3.11-2) which provides the relative motion between the scribing tip and the slice; (3) a precision cross-stage slide and a rotatable vacuum chuck (Assembly C, Figure 3.11-1); and (4) a monocular microscope (Item 1, Figure 3.11-2) used for viewing the slice during scribing and while aligning the slice prior to scribing. Mechanized indexing of the slice is accomplished through a solenoid controlled single revolution clutch, modified for half revolution indexing, driving a 50-pitch precision lead screw.

A locating device was provided to insure proper locating after each index. Variation in the indexing increment is obtained by controlling the number of half revolutions made by the clutch. A single revolution of the clutch produces a .020-inch index, 1-1/2 revolutions produce a .030-inch index and so on. Selection of the index increment is accomplished by shifting the selection lever (Item 2, Figure 3.11-3) to the appropriate position.

To compensate for the variation in stripe spacing, common to germanium slices, a compensating device has been built into the machine. This device permits the operator to reduce the scribing increment .0015 inch maximum. A micrometer has been incorporated into the machine to measure each slice prior to scribing. Correction to the index increment is made by adjusting the expanded scale (Item 3, Figure 3.11-1) to the predetermined setting. Adjustment is made by turning the adjusting knob (Item 4, Figure 3.11-1) in the clockwise direction. The scribing increment is reduced with no change to the index increment by setting the lead screw, drive motor, clutch, and locating mechanism askew to the normal indexing axis.

The scribing and lifting action of the scriber tip is cam controlled and independently driven by Assembly B, Figure 3.11-2. Indexing of the vacuum chuck and table assembly takes place during the return stroke of the scribing tip and is controlled by a limit switch and cam arrangement (Item 5, Figure 3.11-2). The operational sequence of this machine is as follows: (1) the scribing tip drops to contact the slice, (2) the slice moves relative to the fixed scriber tip to produce scribing action, (3) the scriber tip raises, (4) the slice returns to the initial position and is indexed one increment. After approximately 35 scribing passes, the lead screw and cross-stage slide are automatically reset to the start position. After scribing has been completed parallel to the stripes and the machine has reset to the start position, the vacuum check and slice are manually rotated 90 degrees and scribing is resumed.

The operator's duties consist of mounting the slice, aligning the slice, measuring the stripe evaporation error, making the necessary error correction, setting the slice to the start position, starting the scribing action, and rotating the vacuum chuck 90 degrees after completing scribing in one direction.

III Machine Development

A typical manual scribing tool used prior to mechanized scribing is depicted by Figure 3.11-4. Indexing and scribing motions were individual operations performed by the operator. Before the slice could be mounted to the scriber head, each slice was mounted in wax on a glass slide. The limited accuracy and the quality of the scribe produced by this method of scribing did not lend itself to mechanized wafer screening and bonding operations. The hourly output for manual scribing was 2.75 slices per hour. Mechanized scribing resulted in approximately a 400 percent increase over manual methods with an estimated hourly output of 12 to 15 slices.

Studies conducted in connection with this machine included investigating the possibility of holding the slice directly to a vacuum chuck and of making an indexing increment correction to compensate for variation in stripe placement from one slice to another. Studies were conducted to establish the most desirable scribing velocities, to obtain maximum scribing tool life, and to provide the best possible scribing with respect to wafer breaking.

In order to permit the machine to automatically reset to the start position after completing the scribe cycle, a single revolution clutch capable of driving in two directions had to be designed. This was accomplished by modifying a standard spring type clutch.

No device changes affected this machine; however, it was found desirable to modify the machine to permit scribing on any of four indexing increments at will. This feature was not included in the original design and was not added until approximately one year after the machine was placed in shop trial.

IV Operational Problems

Numerous minor problems were encountered during prove-in and early shop trial runs. It was found that the chain used to drive the indexing mechanism caused considerable vibration and was consequently replaced by a timing belt on pulleys. To further reduce vibration, a vibration dampening material was placed under the machine. It was learned that improved braking action could be obtained by replacing the belt-type brake with an electric brake.

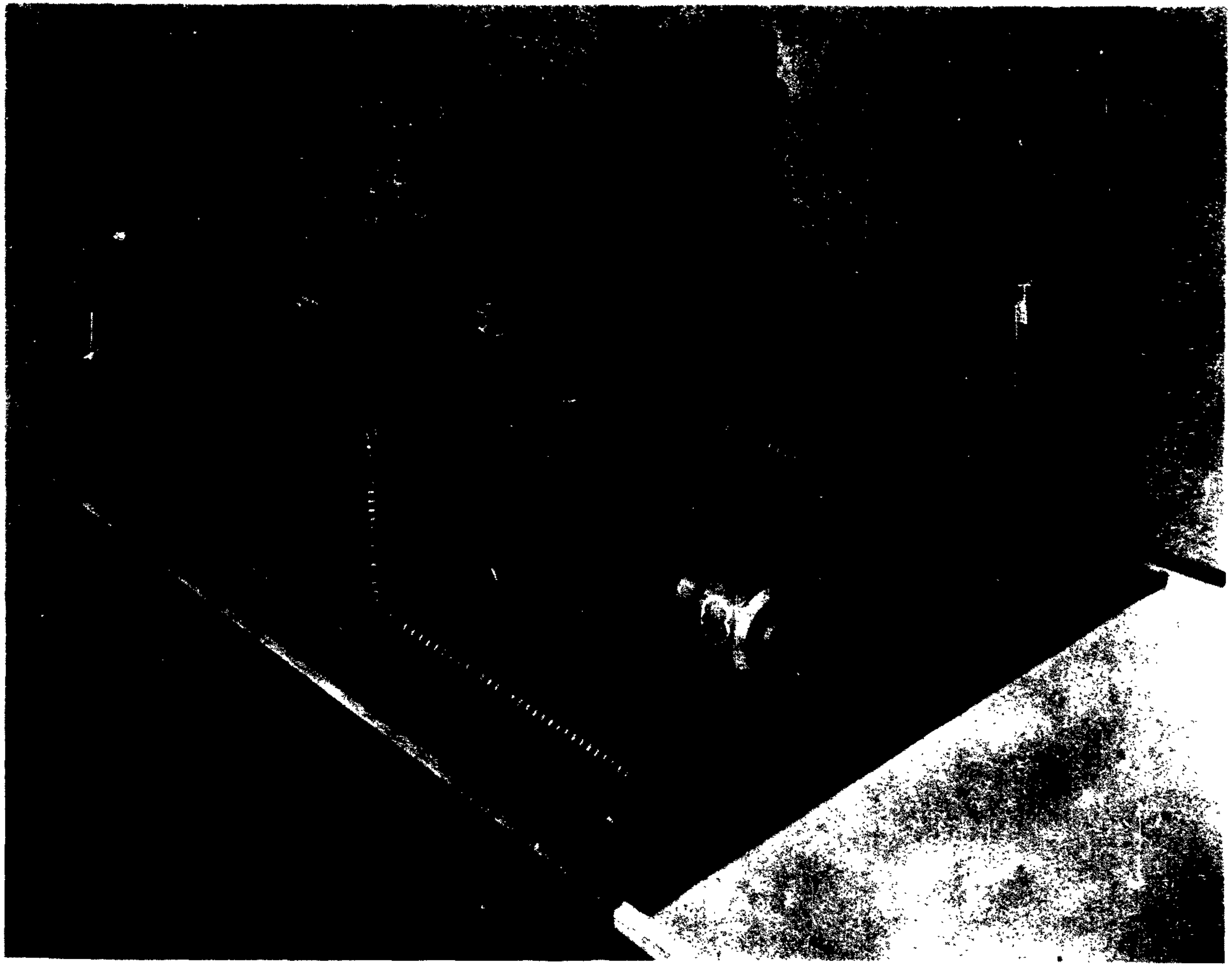
While prove-in revealed no major problems, considerable difficulty was experienced at a later date with the original modified index clutch. As a result, the clutch was redesigned. The improved clutch combines two clutch principles into one versatile and extremely compact unit. This clutch makes use of a spring-type clutch for indexing during slice scribing - while a ball-type clutch is overrunning. When scribing has been completed, the cross-stage slide must be returned to the start position. This is accomplished through the same clutch; however, in reverse drive, the spring clutch is overrunning and the ball clutch provides continuous reversing action.

V Evaluation

The Slice Scribing Machine has performed reliably and continuously for approximately two and one-half years. During this time scribing has been extremely accurate and of a high quality with a minimum of operator effort and machine maintenance. Due to the satisfactory performance and high product yields - in excess of 98 percent - no further work has been scheduled in Phase 2.

VI Conclusion

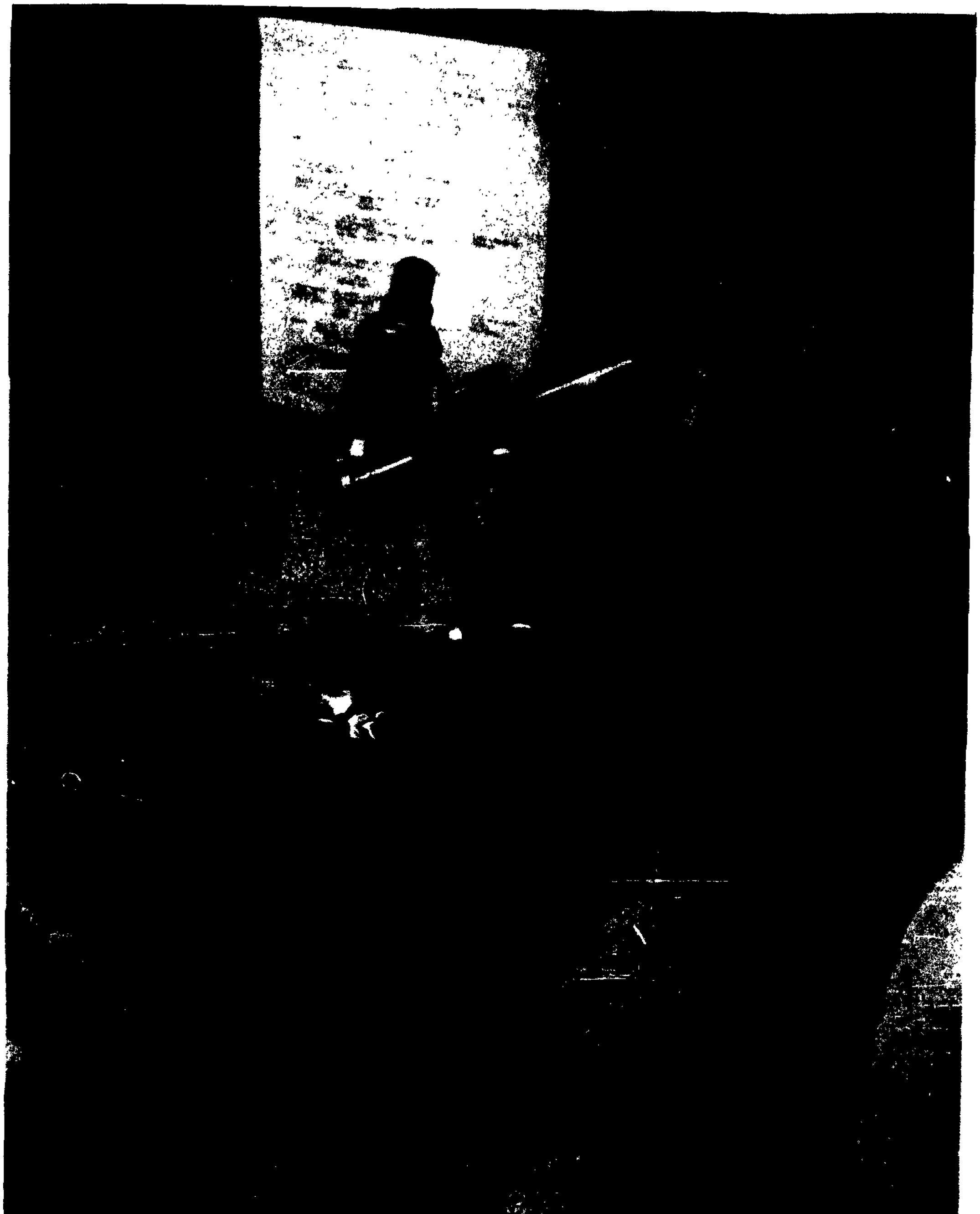
Success in attaining all original goals has been fully realized with the completion of this machine. The wafer processing and handling methods presently in use rely on the scribing accuracy and scribe quality of this and similar machines.



SLICE SCRIBING MACHINE
FIGURE 3.11-1

OPERATING MECHANISMS OF SLICE SCRIBING MACHINE
FIGURE 3.11-2

INDEX SELECTOR OF SLICE SCRIBING MACHINE
FIGURE 3.11-3



MANUAL SLICE SCRIBING TOOL
FIGURE 3.11-4

SECTION 3.12

WAFER BREAKING SCREENING AND LOADING

H. K. Naumann

WAFER BREAKING SCREENING AND LOADING

I General

The 2N559 Wafer Breaking Screening and Loading Machine was built to mechanize the manual breaking, screening, and orienting and loading operations. The estimated hourly output of this machine is 700 wafers per hour. The Wafer Breaking Screening and Loading Machine is of the in-line type and utilizes multi-pocketed wafer trays for wafer handling and storage. A special feature of this machine is that wafer orientation is maintained throughout the process. As a result, no wafer orientation or stripe detecting devices are used and reliability with respect to orientation is very high.

A need for this machine was emphasized by the contemplated high volume Nike Zeus production requirements. Development of this machine has been brought to a successful conclusion.

II Description of Machine

The Wafer Breaking Screening and Loading Machine (Figure 3.12-1) receives scribed germanium slice segments, breaks the segments into individual wafers, passes the wafer under an optical comparator for visual inspection, and then places them into wafer trays for use on associated Wafer Bonding Machines.

This machine consists of the following mechanisms indentified in Figure 3.12-2 by number: strip breaking mechanism (1), wafer breaking mechanism (2), 4-position inspection turret (3), wafer transfer mechanism (4), strip index mechanism (5), and a tray index and locating mechanism (6).

A Nikon Optical Comparator was used as a base for the machine. Electrical components, including relays, transformers, diodes, and fuses are located inside the base and are accessible through doors located on either side of the comparator. Electrical impulse-type counters and comparator controls are located on the front of the comparator. Electrical connection between the machine and the electrical controls located inside the comparator base is made by means of a quick disconnect electrical plug.

Lens focusing is accomplished by means of a vertical slide arrangement provided between the machine and the comparator. Vertical adjustment to the machine can be made by the operator as required. Vacuum and positive pressure air are provided by an air compressor (Item 10, Figure 3.12-1) mounted on the comparator base.

Wafer viewing is accomplished through a Model III Nikon Optical Comparator, equipped with a 300-power detection lens (Item 11, Figure 3.12-2) and a Fresnel type view screen. The comparator light source (Item 12, Figure 3.12-3) is recessed into the comparator base to provide unobstructed access to all critical machine parts located on the machine work top. A 70-watt, tungsten, episcopic lamp illuminates the wafers so that a clear large image can be seen on the comparator screen.

The machine utilized a 110-volt, 60-cycle, operating circuit and a 24-volt D-C control circuit. An ultra-violet lamp was provided to minimize the effects of static electricity on wafer handling. A shield (Item 7, Figure 3.12-2) limits the ultra-violet light to the wafer transferring area.

Mechanized wafer breaking is accomplished by breaking the slice segement into wafer strips, feeding these strips to the individual wafer breaker, and breaking the individual wafers from the strip, one at a time.

The slice segment to be processed is loaded into the slice receptical (Figure 3.12-4). The slice is manually fed into the strip breaker slot in the strip breaker block (see Sketch A, Figure 3.12-6) and the slice lid (Item 8, Figure 3.12-2) is placed into position. To avoid damage to the wafer strips and to permit the slice to slide freely after the lid has been placed into position, approximately .001 inch clearance is provided between the slice and the slot in which the slice is confined.

The slot in the breaker block is designed so that when the block is lowered relative to the slice, a force is applied to the strip and the strip is broken off. This strip is then fed, normal to the longitudinal axis of the strip, into the inspection turret pocket by the strip pusher (see Sketch B, Figure 3.12-6). The strip pusher is .020 inch wide and .003 inch thick and automatically feeds the wafer strip into the inspection turret pocket. Each wafer strip is approximately 20 wafers long; consequently, strip breaking is required every 20 machine cycles. Each machine cycle is energized individually by the operator upon depressing either the accept or reject button. After the strip has entered the inspection turret pocket, the wafer breaker automatically breaks the wafer from the strip. A .010 inch by .020 inch finger holds the slice during wafer breaking to prevent the strip from jumping forward during breaking. After breaking, the wafer is held in the inspection turret pocket by a vacuum drawn through an .008-inch-diameter port in the bottom of each pocket.

The inspection turret serves four positions; they are: wafer breaking, wafer viewing, wafer transferring, and wafer reject, respectively. The purpose of the turret is to transport the wafers to these various positions. The wafers are broken into the turret pocket at the break position after which they are transported 90 degrees counter clockwise to the viewing position. The wafer is then viewed by the operator and either accepted or rejected by initiating the appropriate machine cycle. If the wafer is accepted, it will be removed from the turret pocket and placed into the wafer tray pocket when it reaches the transfer position - 180 degrees counter clockwise from the break position. If the wafer is rejected, no vacuum will appear on the transfer needle and the wafer will remain in the turret until it reaches the reject position - 270 degrees counter clockwise from the break position. Upon reaching the reject position the wafer is vacuumed from the pocket into the reject receptical (Item 9, Figure 3.12-2).

Wafer tray indexing is accomplished by a series of indexing pawls which engage the rack of the wafer tray (Figure 3.12-5) and index the tray .050 inch on each machine cycle. Accurate tray locating is provided by a V-shaped locating tool which enters the rake and locates the tray during wafer transferring.

Electrical controls include the following switches:

(1) The Master On-Off switch controls all power to the machine, air compressor, and ultra-violet lamp.

(2) The Comparator On-Off switch controls power to the comparator light source.

(3) The Accept switch controls the machine accept cycle.

(4) The Reject switch controls the machine reject cycle.

(5) The Load switch activates the strip breaking cycle.

(6) The Strip Index switch provides manual strip indexing.

(7) Accept and Reject Counter switches control counter reseting.

The operator's duties include the operation of all switches and controls, slice segment loading and feeding, and tray loading and unloading.

III Development

Early concepts of mechanized, and partially mechanized, wafer breaking, screening, and loading equipment included various combinations of two and three individual tools; each of which would perform a part of the total objective. These machines would have consisted of a combined scribing and strip breaking tool, a wafer breaking and loading tool, and a wafer screening and orientating tool. A later concept consisted of a wafer loading tool and a wafer screening tool with wafer breaking remaining a manual operation. To facilitate processing wafers in the bulk form, vibratory feeding equipment suitable for handling .020-inch-square wafers was investigated. Also investigated in connection with bulk wafer handling was automatic sensing equipment capable of distinguishing the stripe side of the wafer from the bottom.

As a result of the aforementioned studies, it was concluded that successful wafer breaking, screening and loading depended upon an extremely accurate machine and a minimum of wafer handling throughout the process. Consequently, the wafer breaking, screening and loading operations were combined on a single machine. By breaking the slice into wafers without losing wafer orientation, and screening and loading wafers immediately after breaking, wafer orientation could be maintained with a minimum of wafer handling.

Before design of a machine could be undertaken, a number of prerequisites had to be considered. Scribed slices provided by the manual scribing tools available at the time of these studies were not suitable for mechanized wafer breaking. The quality of the scribed lines and the accuracy of the wafers were considered inadequate and unreliable for a fully mechanized wafer breaking, screening and loading machine. It was this consideration that prompted the early investigation of the mechanized slice scribing machine. A second prerequisite which had to be considered was a suitable wafer tray, or carrier, to facilitate transporting screened and oriented wafers from the screening tool to bonding equipment. A wafer tray was designed and sample trays were built as sketched in Figure 3.12-5. Each tray has 100 square pockets .005 inch deep and .022 inch square.

IV Operational Problems

Early prove-in of this machine revealed that the success of the machine relied considerably upon the accuracy with which the machine was built. It was found that in order to handle individual wafers, the accuracy of many key parts had to be held to plus or minus .0002 inch. As a result, numerous parts had to be reworked. Further prove-in showed that reliability could be improved by relocating the inspection turret pockets on the perifery of the turret and allowing the wafer strip to enter the pocket prior to wafer breaking. Difficulty was experienced during early wafer breaking due to the lack of strip indexing control and a clamp, or hold down finger, to hold the strip during wafer breaking. To provide controlled .020-inch wafer strip indexing, an accurate strip indexing mechanism was designed and incorporated into the machine. To prevent the slice from jumping forward during wafer breaking, a hold down finger was added to the machine. This finger contacts a .010 inch by .020 inch area of the strip while straddling the wafer stripes and holding the strip.

Prove-in revealed a large percentage of the loaded wafers were being blown out of the wafer tray pockets by the puff of air expelled from the vacuum transfer needle as a result of the collapsing vacuum when the wafer was released. Relocation of vacuum valves and a decrease in vacuum tubing diameter corrected this condition.

Wafer strip breaking and wafer breaking was improved by crystal orientating the germanium crystals prior to slicing. The crystal was oriented in such a manner as to place specific crystal planes parallel to the scribe lines. The result of such orientation is to produce wafer strips with clean straight breaks, and sides which are perpendicular to the top and bottom surfaces of the strip. It was found during prove-in that slices polished by electrochemical methods could not be processed through the machine successfully, and that all slices must be held to a specified thickness ±.0003 inch.

V Performance

The Wafer Breaking and Loading Machine has been operating at an average rate of 600 wafers per hour and a process efficiency of 90 percent. A wafer loss of approximately 10 percent is being experienced due to unsatisfactory strip and wafer breaking. Due to the small size of the wafers being handled, it is not believed that this loss can be reduced appreciably. The delicate nature of this machine requires that the operator give it her full and continuous attention at all times. Maintenance, to date, has been limited to the normal cleaning and lubrication specified. The only replacement part required has been the

.003-inch-thick wafer strip pusher.

VI Evaluation

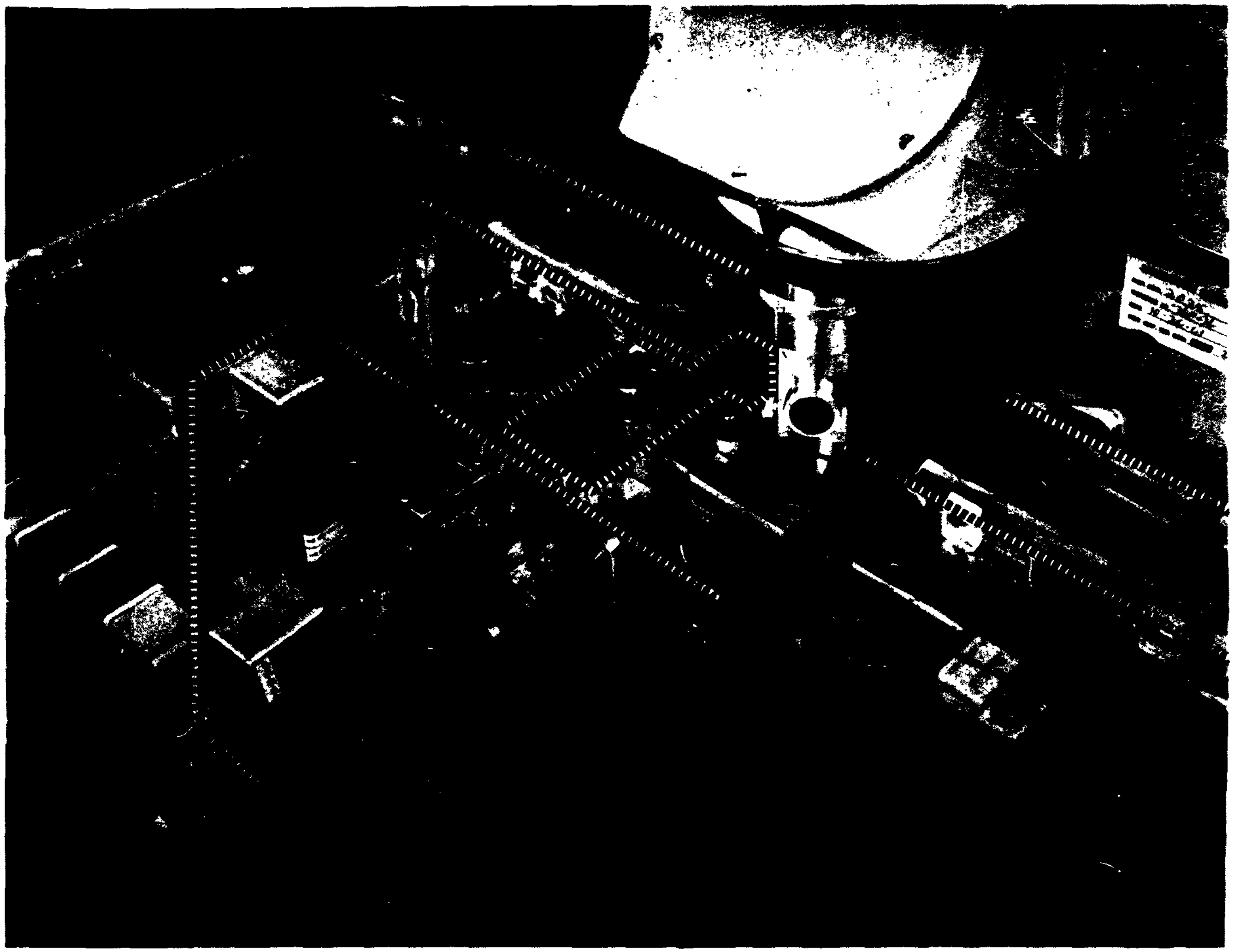
Mechanical and electrical systems of this machine have proven reliable and accurate. Due to the delicate nature of both the machine and the material being handled, above average skill is required of the operator. Slice segment loading and all decisions made with regard to wafer screening remain operator functions. As a result, the estimated hourly output of this machine is affected by operator speed and efficiency.

VII Conclusion

Wafer breaking, screening, orientating and loading has been incorporated into a single machine, requiring a single operator, and capable of screening approximately 700 wafers per hour.. The original goals set for this operation have been fully realized. Wafers processed through this machine exhibit clean, straight breaks and accurate orientation.

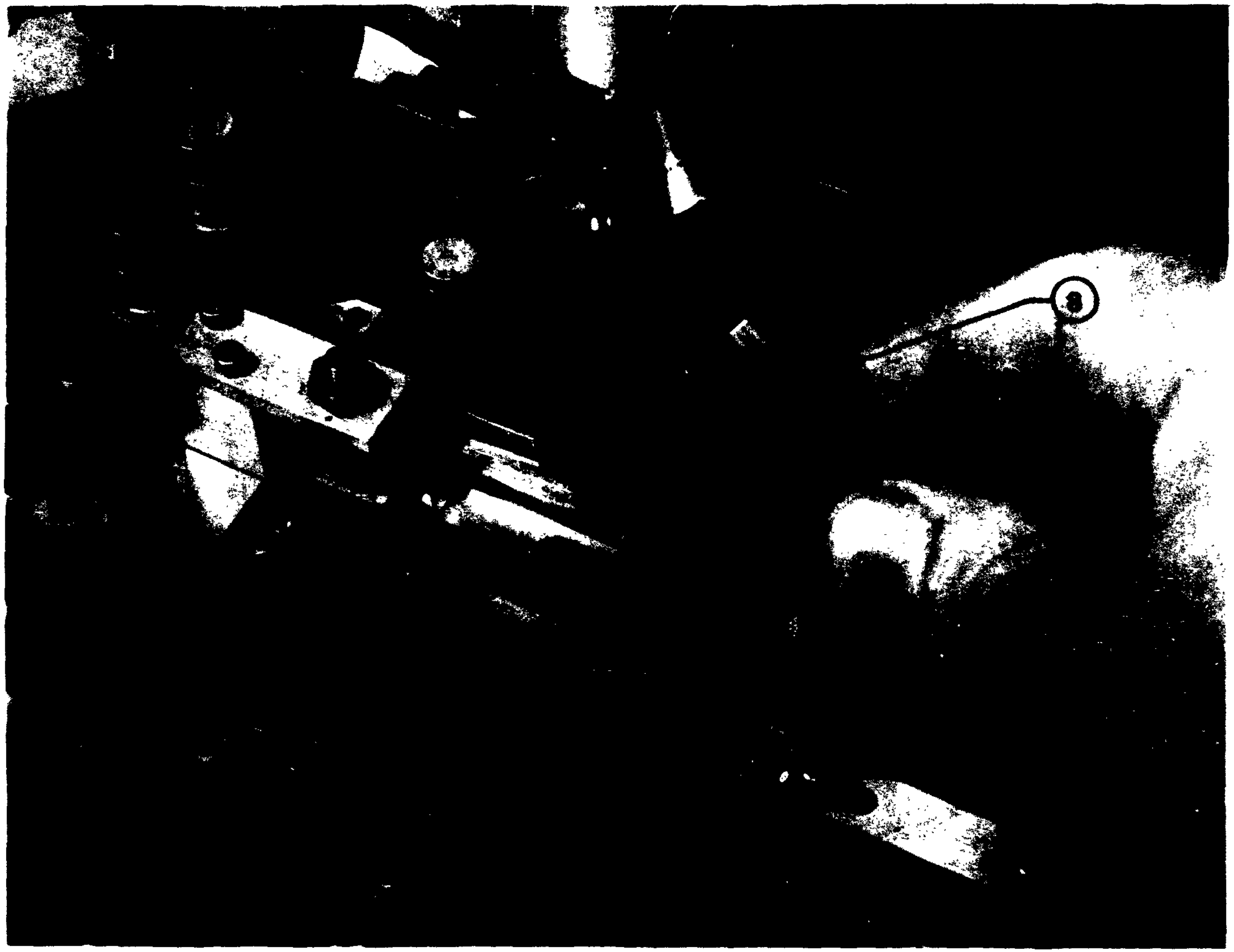
Due to the delicate nature of this machine and the above average skill required on the part of the operator, it is recommended that further development work be done to simplify machine operation. Work proposed for Phase 2 includes building and installing a slice feeding mechanism, similar to the strip feeding mechanism, and an automatic strip length compensating device.

WAFER BREAKING SCREENING AND LOADING MACHINE
FIGURE 3.12-1

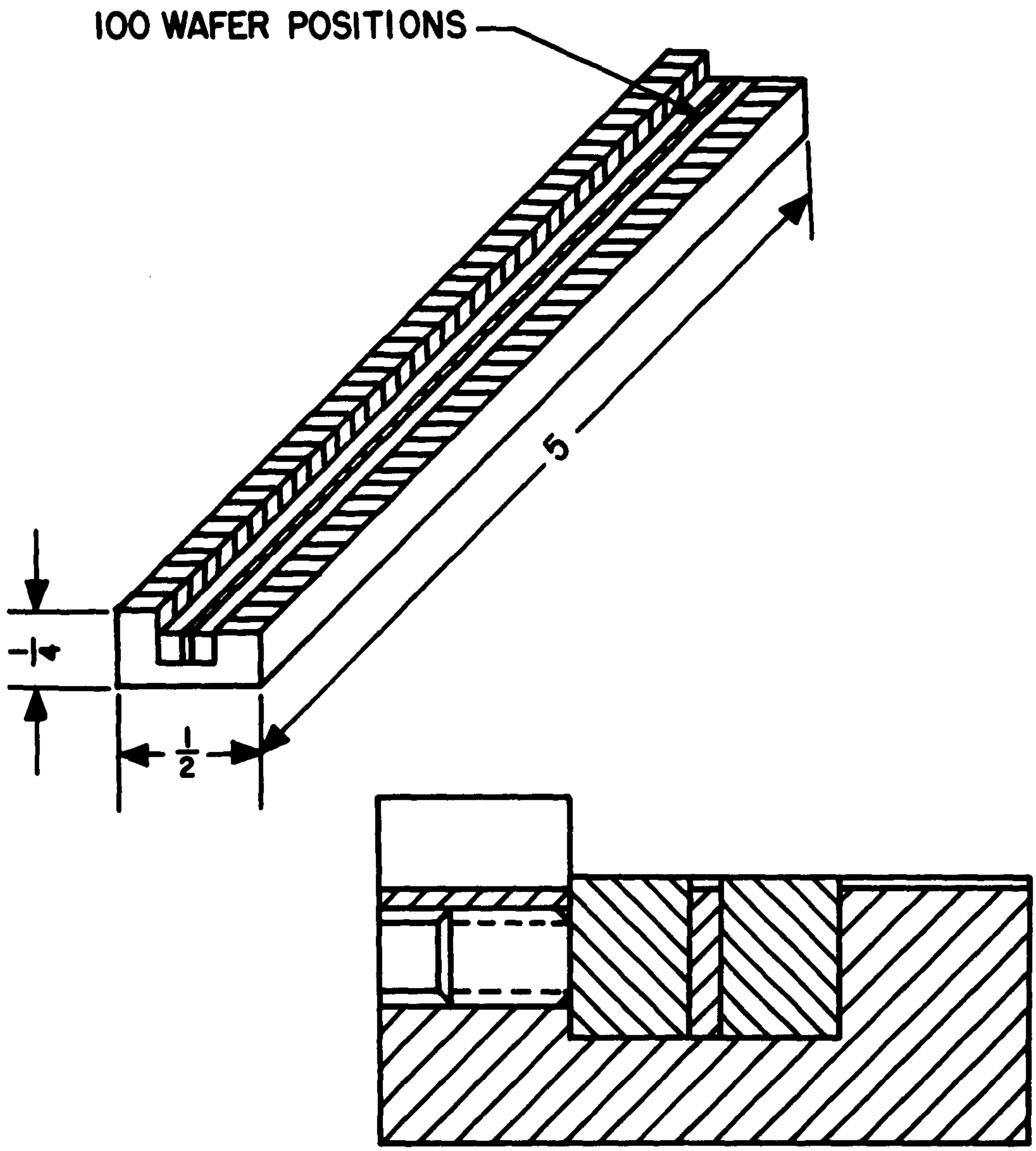


MECHANISMS OF WAFER BREAKING, SCREENING AND LOADING MACHINE VIEWED FROM RIGHT
FIGURE 3.12-2

MECHANISMS OF WAFER BREAKING, SCREENING,
AND LOADING MACHINE VIEWED FROM LEFT
FIGURE 3.12-3



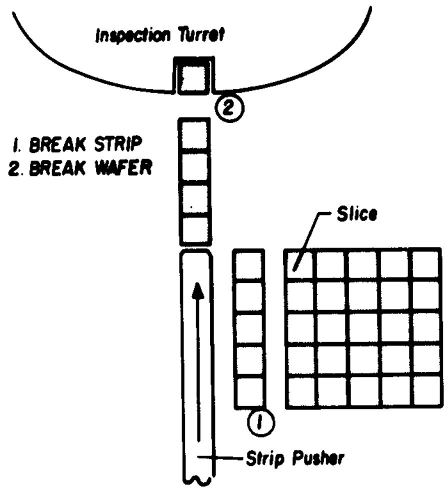
SLICE RECEPTICAL OF WAFER BREAKING,
SCREENING AND LOADING MACHINE
FIGURE 3.12-4

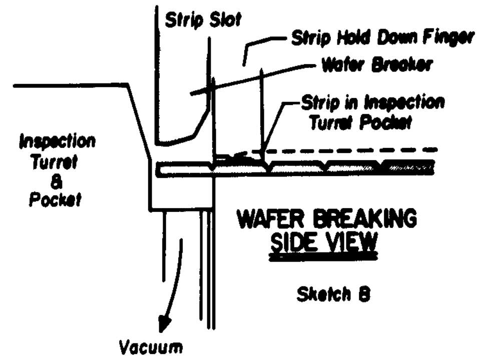


WAFER TRAY SKETCH

FIGURE 3.12-5

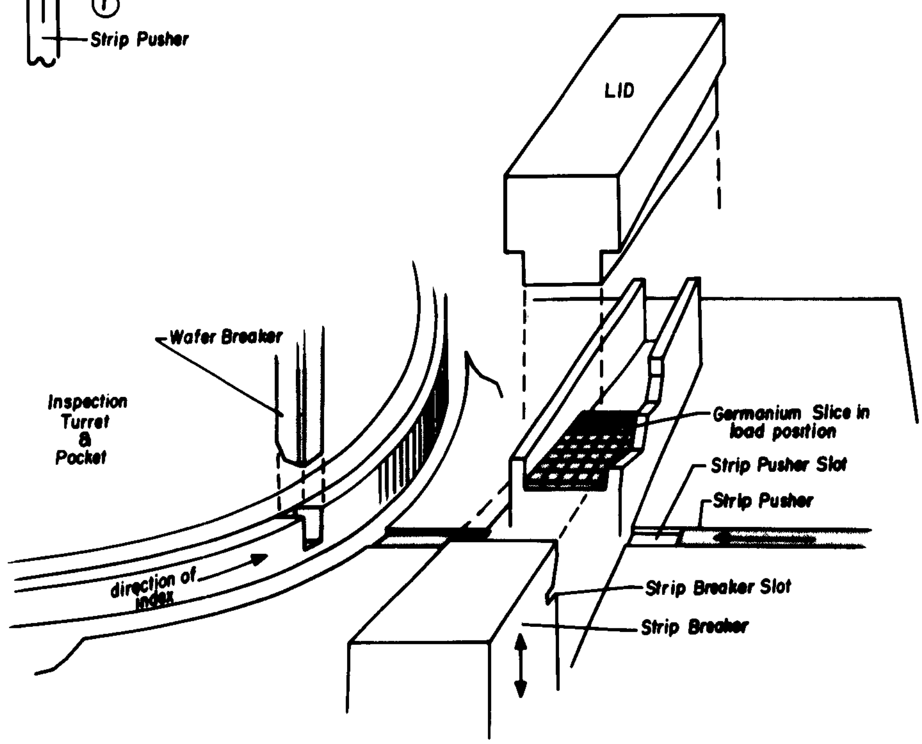
TOP VIEW OF BREAKING SEQUENCE

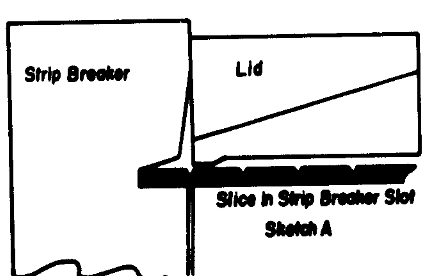




WAFER BREAKING
SIDE VIEW

Sketch B





Sketch A

SIDE VIEW

WAFER BREAKING PROCESS
SCHEMATIC

FIGURE 3.12-6

SECTION 3.13

WAFER BONDING

Q. L. Schmick

I General

II Description of the Machine

III Machine Development

IV Operational Problems

V Evaluation

VI Conclusion

WAFER BONDING

I General

The Wafer Bonding process includes the eight operations which unite the wafer to the gold plated header. Six of these operations are, primarily, handling functions which prepare the header and wafer for the bond. Bonding involves the two remaining operations and is performed to create an ohmic contact between the wafer and header. This bond, or contact, must be mechanically strong, thermally and electrically conductive, and without capillary voids. The wafer must be accurately placed on the header in preparation for reliable wire bonding.

The manual process, involving 14 operations, resulted in yields and rates which were too low to be compatible with the anticipated Nike-Zeus production requirements. Since maximizing the yield would not sufficiently increase the output, greatly increased production rates were necessitated. This was accomplished by both the elimination of the many handling functions and by decreasing the time required to prepare for the bonding operation. With the introduction of a "quick-heat" process, the yield was improved and the rate was increased.

II Description of the Machine

All operations are performed by a combined in-line and turret type, intermittent motion machine (Figure 3.13-1) having 40 header carriers in a rectangular track (Figure 3.13-2). These carriers are designed to accept an oriented header, clamp and hold it accurately while allowing access for processing tools. The tools are mounted along one of the rectangular sides of the track which provides for 11 tooling

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To load a header, the operator pre-positions the tab of the header to the left and drops it, leads first, into the load tube. Since this may be done at any time during the cycle, an escapement prevents the header from dropping too far until the carrier is properly positioned. As a cycle nears completion, an empty carrier (Figure 3.13-3) is positioned under the load tube and a push rod raises the spring nut which, in turn, raises the collet. The cam surface on the collet rises above the bushing allowing the collet to open. After the solenoid of the escapement is energized, the header drops to the bottom of the load tube and the leads enter the hole in the anvil.

By pressing the start button, the operator initiates a cycle. The header is transferred to the carrier by the loading mechanism. A locator captures the emitter and base leads before the loading mechanism retracts. While the locator holds the header, the collet depresses to clamp the header flange between the collet and the anvil. With the header clamped in its proper orientation, the carrier is indexed to the next position which in addition to the next four positions is an idle station.

While the header indexes through the idle stations, the wafer is being transferred to the bonding position. To perform the wafer transfer function properly, a small vacuum pump is used to evacuate a hypodermic-type pick-up needle in the bonding head (Figure 3.13-4). The wafers are delivered to, and loaded into, the machine by means of a tray which maintains the required wafer orientation. When the bonding head is indexed over the wafer pick-up position, a ball detent holds the needle "up" as in Figure 3.13-4A. At this time, the top groove of the needle coincides with the top groove of the bonding head while the bottom groove is blocked. As the head lowers, the tip of the unevacuated needle is properly positioned over the wafer. The downward motion of the needle is limited by the tray before a positive stop applies a force on the top of the needle. When the bonding head is raised, the top groove becomes blocked and the bottom grooves align to permit the needle to be evacuated. The wafer is held against the tip of the needle; the positive stop is removed, and the entire bonding head assembly rises to pick up the wafer (Figure 3.13-4B). The wafer is indexed through two idle stations to the bonding station.

At this station both the bonding head and the wafer are in position to start the bonding cycle (Figure 3.13-4B). A bonding mechanism actuates the electrode depressors. The electrodes contact the header while the agitator spring contacts the needle; thus the bonding mechanism initiates the heating cycle. After the header has been properly heated, the bonding head is lowered until the wafer contacts the header, and the eutectic begins to form. As the bonding head continues to move down, the agitator contacts and excites the spring; the needle moves to the "up" position, and the ball detent applies the compression needed to make the bond (Figure 3.13-4A). At the same time, room temperature nitrogen fills the needle and exits onto the top of the wafer to ensure its release and to cool the stripes. Shortly after the turret containing the bonding head starts up, the heating cycle is terminated and the electrodes are lifted. When the wafer loading turret reaches its uppermost limit, all of the indexes take place: header carriers, wafer loading turret and header unloading turret.

After three indexes, the wafer bonded header is at the unload station still clamped in the carrier. At the start of the unload cycle the unload head, which is a nylon sleeve actuated by fixed stops, lowers over the header as a solenoid raises the collet of the carrier. This sleeve, which fits snuggly around the platform, captures the header and lifts it from the carrier. The unload turret then indexes to a position where the header is loaded into a header tray. This header tray, which has a 15-header capacity, is loaded into the machine from a header magazine. At the same time, 15 tray covers in a cover magazine are loaded into the machine. As the wafer bonded headers are being loaded, the tray slides onto a cover. After the tray is full and the cover is in place to protect the finished units, they are loaded into another magazine.

In general, the mechanical systems consist of well-known components,such as motors, linkages and cams. The electrical system, which does not involve electronic devices, also utilizes common electrical components,such as relays, switches and solenoids. Since well-known components are used, the maintenance and lubrication is performed as a function of either time or running schedule. Standard lubricants easily obtained are used at specified time intervals during normal running schedules; heavier operating schedules necessitate more frequent lubrication. Although this machine has not operated continuously through a single shift the predetermined lubrication and maintenance schedules have resulted in no component failures.

The operator's major duties are to load the machine and to initiate the cycle. The operator can cycle the machine either by actuating a foot pedal or the start button. Cycling may also be placed on timer control by simply twisting the start button. The timer control was provided because the optimum rate of the machine is 1800 bonds per hour. An operator is able to manually load 900 headers per hour. If the operator initiates each cycle, however, the loading rate is decreased to 600 headers per hour. Although the bonding cycle is adjustable, it is unaffected by the adjustments made to accomodate the operator's loading ability. Other loading functions of the operator include the loading of wafer and header trays and covers, plus unloading the same. Header trays and covers must be changed approximately three times per hour, while wafer trays must be changed every 45 minutes. The major duties of the operator have been simplified by the "safety circuitry" described in the next paragraph.

Surveillance of the machine by the operator is one of the most important operator duties. In the event that the operator neglects any of the loading and/or unloading functions, a low voltage "safety circuit" stops the machine. When the machine is safe to run, all the indicator lights on the control panel are green. As the wafers and header supplies near exhaustion, the indicator lights change to yellow. After complete exhaustion of these supplies, the indicator lights denoting this state change to red and the machine is stopped until the supply is replenished. The most important function of this safety circuit is to protect against mechanical failure of the machine.

III Machine Development

When this process was done manually, a single bench fixture was used to perform the 14 operations which produced a wafer bonded assembly. In this fixture, the header was heated by conduction in a heated nest. Due to this heating effect, the nest would move. As a result, the operator had to proceed cautiously to assure that the header did not move under the wafer which would result in an inaccurate wafer location.

Inspected headers and wafers were delivered to the bonding tool in batch form. The wafers were placed on a small plate which was provided with a pair of "knife-edges" to create a corner for orientation of a single wafer. A header was loaded into the nest with the tab oriented in a slot, and a toggle clamp was closed upon the header flange. The operator burnished the wafer area of the header with the tip of the tweezers after which a wafer was transferred from the corner of the knife edges to the header by an evacuated hypodermic needle. After initiating the preheat cycle of approximately 30 seconds, the operator separated another wafer from the batch and pushed it to the area of the knife edges. The spike heat cycle of approximately 15 seconds was automatically started after the pre heat cycle was completed. While the bond was being made, the operator oriented the wafer and placed it against the knife edges. The evacuated needle on a transfer arm was removed from the header and placed over the newly oriented wafer. After this, the bonded assembly was unclamped, unloaded and placed in a transfer tray.

At the beginning of this development, the slow heat cycle of the manual bonding tools limited the operation to 80 bonds per hour. To increase the output of this process, the primary objective was to find a process that would increase the rate at which bonds were made. A secondary objective of increasing the yields was also necessary. The yield was improved by reliably locating the wafer on the header, and the rate was increased by eliminating some of the operations and introducing a new heating process which is called the "quick-heat" process.

Feasibility studies for the header loading, locating and unloading were made on a mock-up fixture which was used for carrier studies. This fixture, designed much like a die set, had a lower plate which was used to locate a mock-up of the header carrier. Above this lower plate, another plate with appropriate slotting and a hole was used to preposition the header. Over this plate a pair of wires contacted the emitter and base leads while above the platform a collet was introduced from the top to clamp them. The wires and the plate were swung out of the way and the header was transferred to the carrier manually. This mock-up fixture worked by virtue of the height of the lead above the header - .140 inch.

Two other mock-ups were used to investigate the feasibility of the "quick-heat" process and electrode life. The first mock-up was a fixture which accepted an oriented header and transferred the wafer in the same manner as the manual bonder. A pair of electrodes contacted the sides of the header which is used as a resistor. Although the header was preheated to a temperature just below the eutectic temperature, the heating pattern was unpredictable. As a result, the heated area was reduced. A new pair of electrodes were made. These contacted the header on the top, allowing only enough room for the wafer and a small amount of eutectic (Fiugre 3.13-5A). At the same time, wafer trays were completed and the required mechanisms were added to the mock-up. These changes increased the accuracy of both the heating pattern and wafer location, eliminated the necessity for a preheat cycle and proved the feasibility of the "quick-heat" process.

The second mock-up was designed to recycle a pair of electrodes contacting a header continuously. This was done to investigate the life expectancy of the electrode. With copper, redressing every 50,000 cycles was needed. Depending on the amount of electrode removed during redressing, the electrode life varied between 150,000 and 200,000 cycles.

Based on the feasibility results, the design of the machine was started by a subcontractor. During this period, two device changes resulted in delays. Both changes involved decreasing the height of the internal leads which finally resulted in a different header loading concept. When the design was complete, the machine was started in construction. There were no device changes during construction after which the machine was installed in the prove-in area and test runs were made. After some adjustments were completed, an evaluation run was made. A control lot processed manually produced a 55 percent yield. The lot bonded by the "quick-heat" method on the Wafer Bonding Machine had a 68 percent yield. Another evaluation run indicated that wafer stripes were centered between the internal header leads to an accuracy of ± .005 inch with the manual equipment, compared with ± .0015 inch with the "quick-heat" Bonder.

The next device change, involving the gold plating on the header, affected the results of the "quick-heat" Bonder radically. Insofar as the gold was harder, both the header resistance and the electrode contact changed. After trying many metals, the electrode contact was improved by changing from a copper tip to a special alloy of silver and tungsten. After this, the contact was further improved by changing the profile of the tip (Figure 3.13-5A). An elliptical area was found to be the best, resulting in the heating pattern shown in Figure 3.13-5B. There is a hot spot between the posts, with steady and slight cooling to the contact areas which are slightly warmer but not as warm as the hot spot.

Two other effects, due to the change in gold plate, involve the heating curve and the time at which the wafer is bought in contact with the header. In the original heating system, a 250-watt transformer was used to convert the primary voltage. With a primary voltage of 60 volts, the current across the header was 35 amperes at 0.60 volts. The harder gold plate would not form a eutectic using the original heating curve shown as a dotted line in Figure 3.13-6B. (Since the time lag inherent in temperature recording devices prohibited their use in this short time range, the curves shown are based on point indicators - temperature colors). An electrical control circuit was added to refine the control and divorce the heating cycle from mechanical elements. With the use of a cam on the main shaft, voltage curve traces were used to shorten and refine the heating cycle (Figure 3.13-6A). The heating cycle was divided into a "preheat" portion and a "hold" portion. A primary voltage setting of 102 volts resulted in a current across the header of approximately 40 amperes at 0.95 volt. This heated the header to the eutectic temperature, after which the "hold" portion was initiated. Dropping the primary voltage to 86 volts, a voltage of 0.80 volts at approximately 37 amperes was used to "hold" the eutectic temperature. The wafer is placed on the header after two-thirds of a second (40 cycles) and agitated. The effect of these changes has improved the output of the "quick-heat" Wafer Bonding Machine.

IV Operational Problems

At the start of the prove-in phase, the carrier index system was unreliable due to carrier misalignment at the corners of the track. Mechanical helpers were designed and installed to overcome this defect. Although carrier jamming has not occurred since the helpers were installed, a jam can damage other machine elements. To protect against this, two shear pins were added in the main drive system.

As prove-in progressed, the loader for the header tray cover was found to be unusable. The action from this mechanism destroyed the covers. As a result, a new mechanism was designed and installed. This mechanism has proven to be reliable and easier to maintain.

Finally, the header heating system was not reliable initially. With the old design, the header was heated by a pair of electrodes in each of six bonding heads. Since each pair of electrodes was subject to variable contact pressures, a single pair of electrodes was designed and installed. These changes improved the operation of the machine and evaluation runs were started.

During the evaluation runs, minor problems caused occasional mechanical failures. These problems are confined to the areas of wafer transfer and header loading and unloading. Header loading is a problem when the header tabs have pronounced burrs. The burrs cause the tab to bind in the pre-positioning grove of the header load tube. Enlarging this grove will solve this problem without affecting the pre-positioning function of the load tube. At the unload station, header loading is not as reliable as desired. Header diameters approaching the maximum dimension expand the nylon pickup sleeve; this makes header unloading erratic when the diameter nears the minimum dimension. It appears that this problem can be remedied by slotting the nylon sleeve radially at two or three places.

New cleanliness critera are being investigated to alleviate a cleaning problem with the wafer transfer needle. It has been established recently, that dirty wafers cause unreliable wafer pick-up. After approximately 1000 to 1500 wafer transfers, the needles need cleaning.

V Evaluations

Evaluations of units bonded during Phase 1 indicated that the wafer bonding yield has been improved to some degree by the mechanized operation. The majority of rejects could be assigned almost equally to two separate defects: The first defect is called "punch-through", which means that the emitter stripe has been diffused through the primary junction due to excessive heat. Incomplete bonds, which are the second defect, are generally due to the combined effects of piece part variations, insufficient heating, dirt and/or oxidation.

Two unique concepts, used on this machine, involve the manner in which the headers and wafers are handled. Headers are oriented and clamped during the entire machine cycle. The header transfer system has not performed perfectly; it could be improved with very little effort. The wafer transfer system, which picks up a wafer and transfers it to the header, is especially reliable. A pick-up needle, affixed to the end of a valve spool, is alternately evacuated and pressurized to pick-up and release the wafers. The alternate needle conditions are controlled by the relative motion between the valve spool and the bonding head. This concept allows for very precise and reliable locations of the system cross-over points.

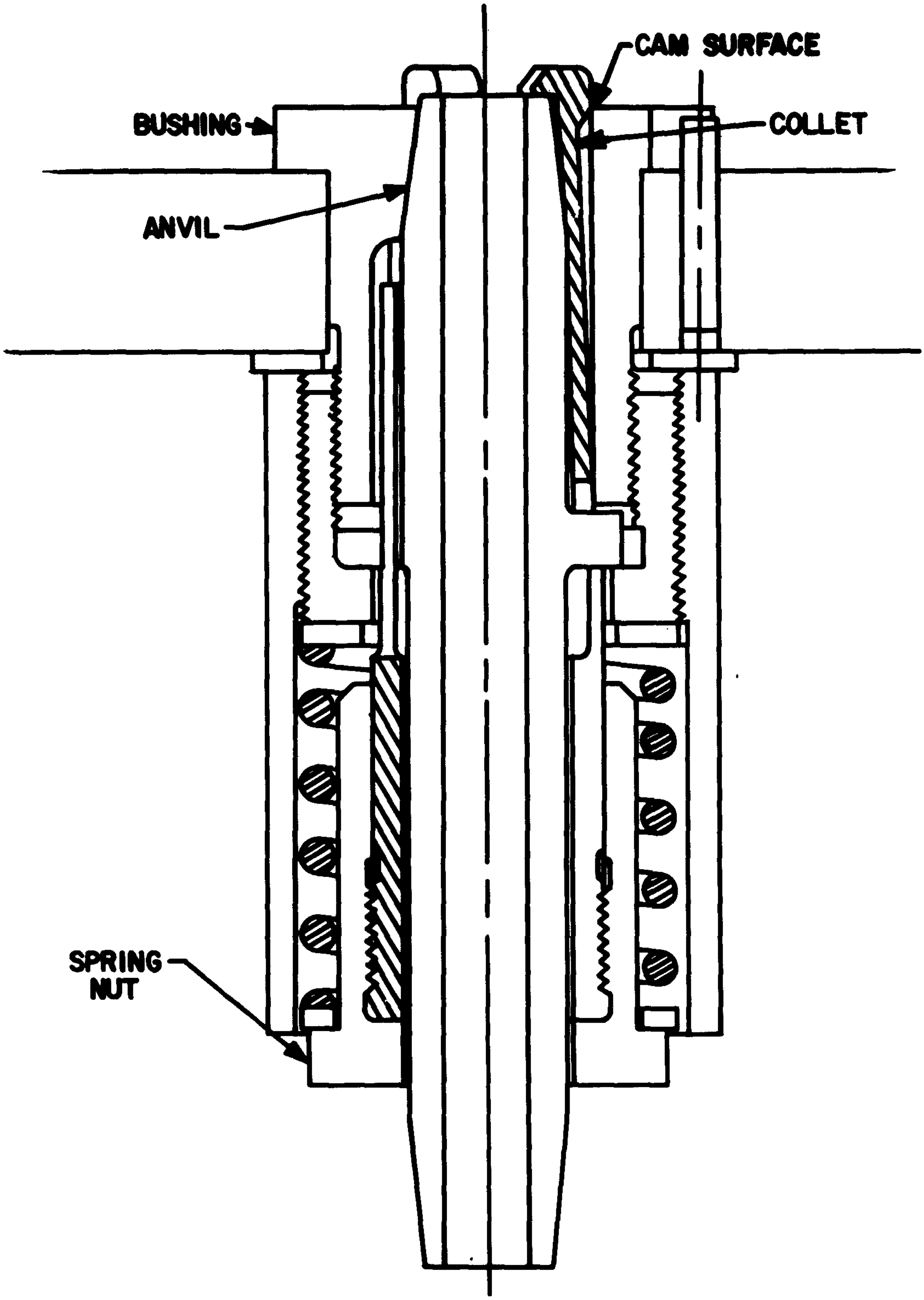
The most unique feature of this machine is the manner in which heat is supplied to the bonding area. Since the heated portion of the header is confined to a small area, the heating time is especially short. Most of the headers bonded by the "quick heat" method have been evaluated for defects due to thermal stressing. The small amount of glass cracks found along the glass-to-metal seal indicates that thermal stressing was not excessive. Other evaluations indicate that the "quick heat" process does not degrade the electrical characteristics of the transistors. By virtue of this "quick heat" process, the wafer bonding rate has been increased from 80 bonds per hour to 900 bonds per hour.

VI Conclusion

In view of an increased yield at 900 bonds per hour, it appears that this machine is capable of obtaining its originally conceived goals. This is possible by virtue of the accelerated heating cycle. The header heating time was decreased from 45 seconds to less than one second. Due to the "quick heat" process and elimination of some operations (Figure 3.13-6), an overall improvement is realized in that a single operator is able to bond 80 units per hour (net) manually; while a single operator is able to complete 900 units per hour with the Wafer Bonding Machine. In so far as this machine has decreased the time required to perform the wafer bond, this improvement has increased the capability to manufacture TO-18 devices.

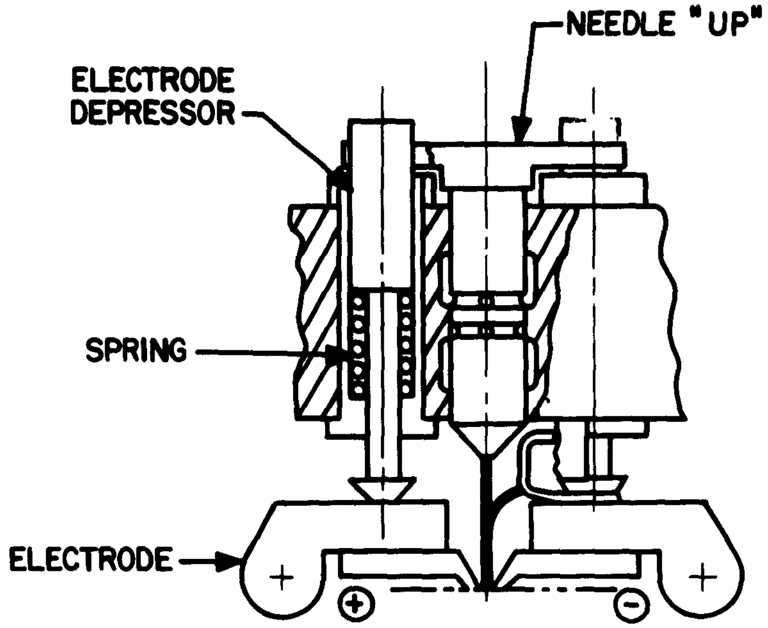
WAFER BONDING MACHINE
FIGURE 3.13-1

CONTROL PANEL AND WORK STATIONS OF WAFER BONDING MACHINE
FIGURE 3.13-2

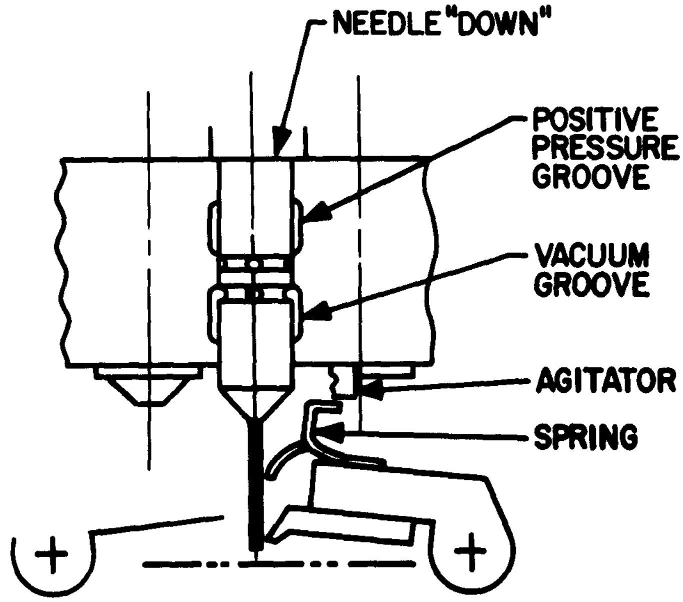


CROSS SECTIONAL VIEW OF HEADER CARRIER
ON WAFER BONDING MACHINE

FIGURE 3.13-3

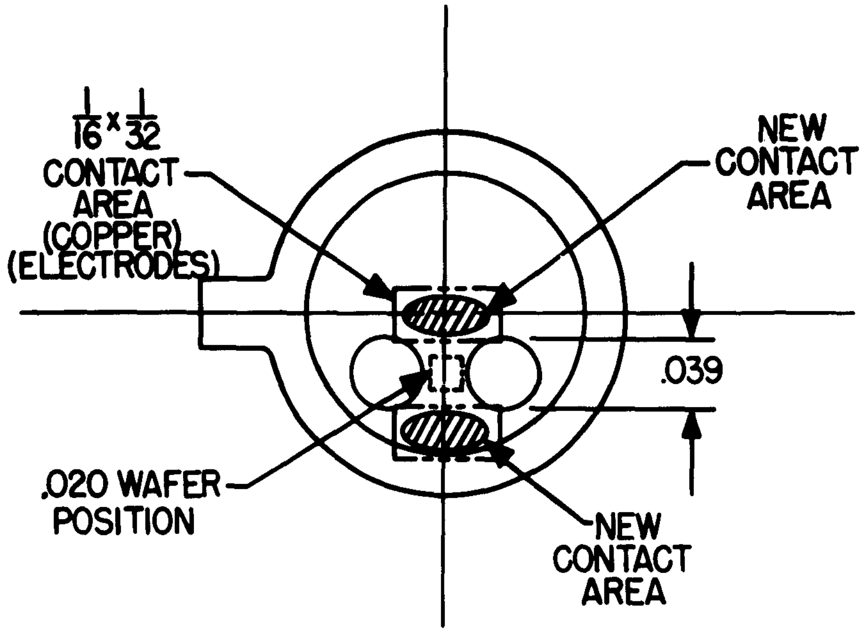


A. HEATING HEADER AND BONDING WAFER WHILE AGITATING SAME



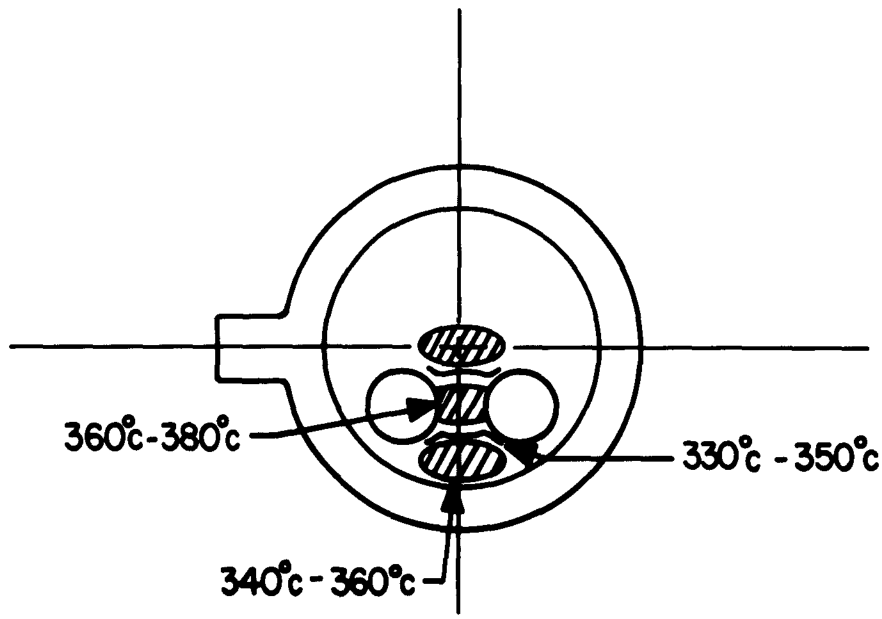
B. WAFER TRANSFER ELECTRODES UP

FIGURE 3.13-4



A.

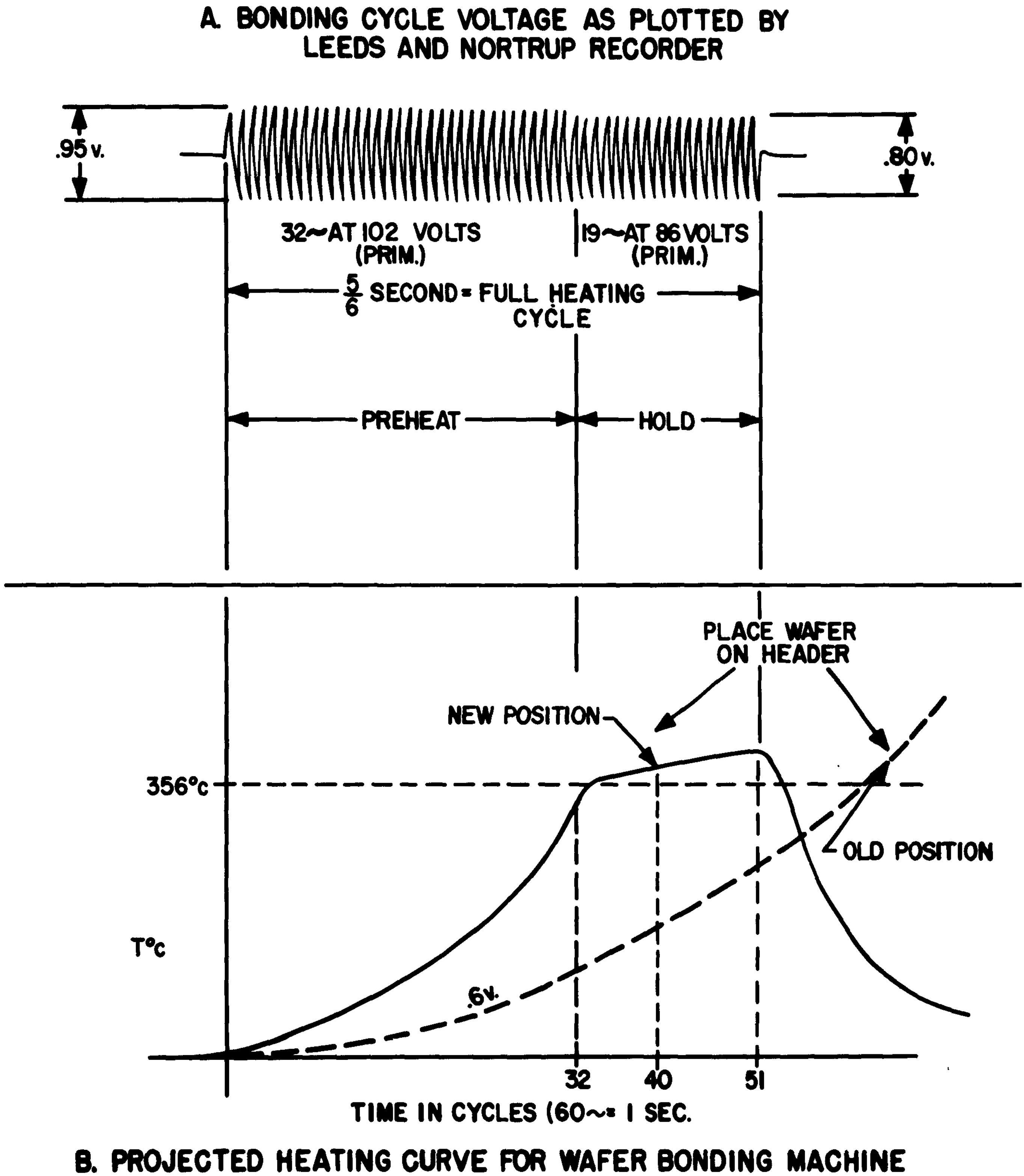
PLAN VIEW OF HEADER
SHOWING ELECTRODE CONTACT AREAS



B.

HEAT PATTERN RESULTING
FROM NEW CONTACT AREA

FIGURE 3.13-5



A. BONDING CYCLE VOLTAGE AS PLOTTED BY LEEDS AND NORTRUP RECORDER
.95 v.
.80 v.
32~AT 102 VOLTS (PRIM.)
19~AT 86 VOLTS (PRIM.)
5/6 SECOND = FULL HEATING CYCLE
PREHEAT
HOLD
PLACE WAFER ON HEADER
NEW POSITION
356°c
OLD POSITION
T°c
.6v.
32
40
51
TIME IN CYCLES (60~= 1 SEC.
B. PROJECTED HEATING CURVE FOR WAFER BONDING MACHINE

FIGURE 3.13-6

WAFER BONDING PROCESSES

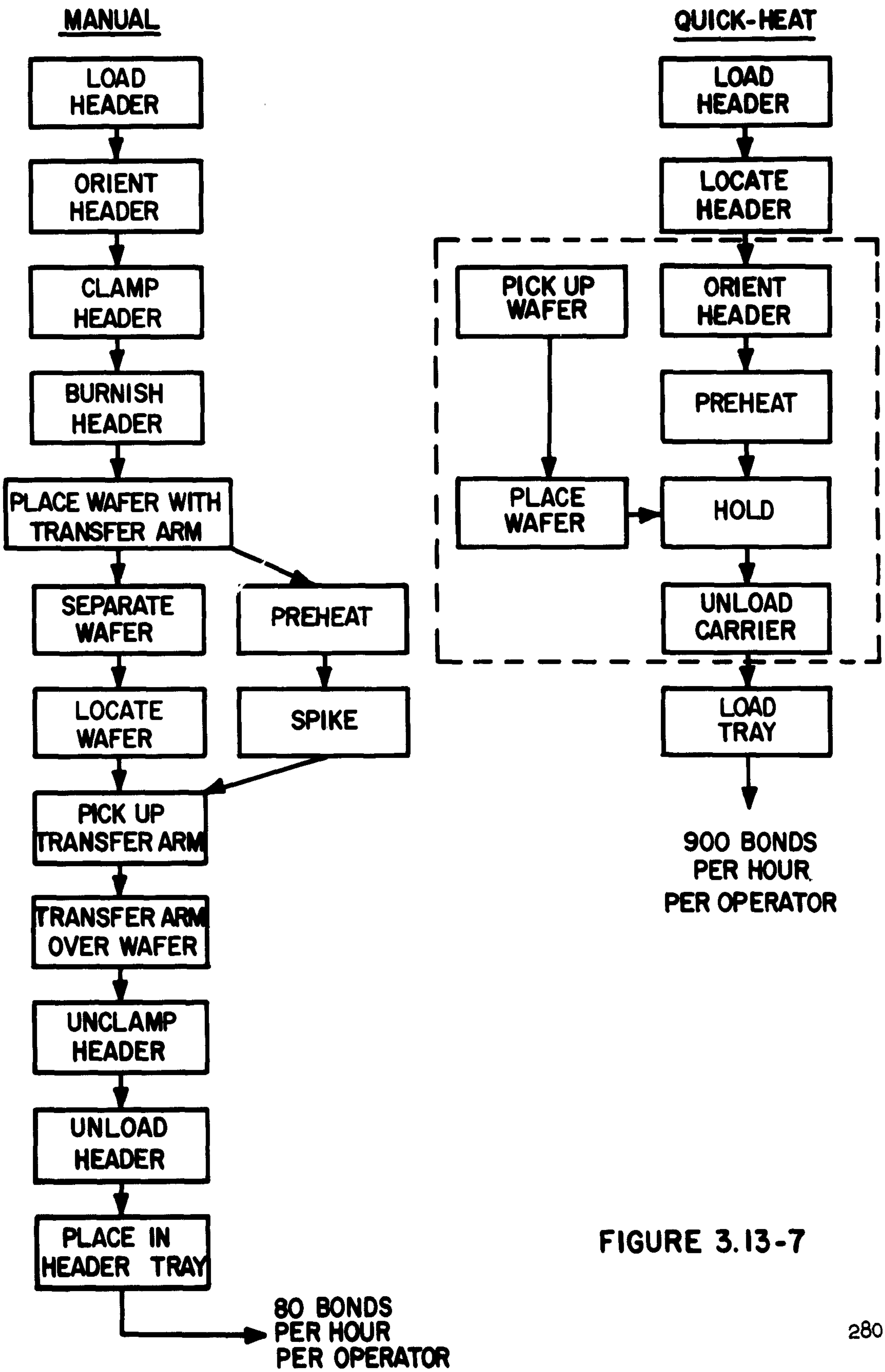


FIGURE 3.13-7

SECTION 3.14

WIRE BONDING

M. K. Avedissian

WIRE BONDING

I General

The Wire Bonding Machines attach small diameter gold wire to stripes on the semiconductor wafers and to appropriate internal header leads. Header assemblies, previously wafer bonded and loaded in magnetic trays, are transferred through the machines. As these assemblies pass through the bonding station, the gold wire is attached to the proper stripes and internal leads by thermocompression bonding. The bonds produced by these machines must be capable of withstanding 20,000g's acceleration.

II Objectives

The manual operation used prior to the development of these machines is slow and involved:

First, the operator places the wafer bonded platform in the wire bonding tool; then she places a block with a piece of silver jacketed gold wire in the tool. One end of the silver jacket was previously etched away to expose the core of gold wire. Then the operator manipulates six micro-manipulator screws in order to make the bond to the one stripe. After completion of this bond, she must operate a lever to perform the bond to the appropriate internal header lead or post. After making the bond to the post, the operator must again manipulate a micro-manipulator screw to break the gold wire loose from the post. This completes wire bonding of one half of the device. The same procedure is repeated to wire bond the other half of the device. Figure 3.14-1 shows a typical manual wire bonding tool and 10 of the 11 micro-manipulators used in the manual Wire Bonding operation.

The average hourly output of the previously described manual operation is approximately 60 units per operator. However, one extra operator is required for every two wire bonding operators to load silver jacketed gold wire in the wire holders and prepare the wire for the bonders by etching the silver jacket to expose the gold wire. Therefore, the average hourly output per operator is approximately 40 units. The operation requires an appreciable amount of skill and judgment by the operator.

The objectives for development of the wire bonding machines were several:

1. Eliminate the use of silver jacketed wire and its associated preparation.
2. Use continuous gold wire feeding system.
3. Increase rate of production by mechanizing auxiliary operations such as header handling.

In view of the anticipated increase in production requirements it was necessary to develop equipment capable of fulfilling these objectives.

For the manual as well as for the mechanized operation the principle of the thermocompression wire bonding, developed and patented by the Bell Telephone Laboratories is used. In view of the present state-of-the-art, this principle appears to be the most reliable if the factors necessary for thermocompression bonding are recognized and proper conditions are provided, such as proper temperature, pressure and above all cleanliness of the surfaces to be bonded. These surfaces must be, as perfectly as possible, free of all organic an inorganic contaminations. The necessity of a clean operation can not be considered to be a shortcoming of the principle of thermocompression wire bonding, since cleanliness is also of utmost importance for the reliability of the devices.

Variables inherent to the materials used must also be considered since they have an influence on rate, yield and reliability. Attempts have been made to develop methods of reducing or possibly eliminating this influence and the preliminary results are encouraging. Work in this direction will be continued during Phase 2 of this Contract.

III Description of the Machines

Two machines were developed to perform Wire Bonding operations according to the objectives outlined above. Both machines use the Stitch Wire Bonding method, developed by the Western Electric Research Center in Princeton, New Jersey, which permits fast Wire Bonding operation. In this report these machines will be referred to as Machine No. 1 (Figure 3.14-2) and Machine No. 2 (Figure 3.14-3 and Figure 3.14-4). The bonding tip used for the stitch wire bonding operation performs two functions: one function is to guide the gold wire to the point to be bonded; the other function is to perform the bond.

The design production rate of Machine No. 1 is approximately 150 units per hour and of Machine No. 2 is approximately 300 units per hour. The wire bonded units have tails of wire at the posts which are removed at a subsequent operation. Presently the removal of these tails is done manually. One operator can remove these tails from approximately 900 units per hour.

The components of Machine No. 1 (Figure 3.14-2) are mounted on a base plate. An X-Y-Z micro-manipulator (1,2) permits a fine alignment of the bonding tip (3) to the parts to be wire bonded. The bonding arm (4) carries the bonding tip and the spool holder (5) with the spool and gold wire. Under the bonding arm is the cutting device (6) used to cut the wire after completion of the bond. The bonding nest (7) is capable of a 180 degree rotation to permit bonding of both sides of the device. The devices are supplied to Machine No. 1 in magnetic trays, which are placed in a track (8). An index mechanism brings the units into proper position to be loaded into the bonding nest. The loading is accomplished manually with appropriate tweezers.

Control valves, air regulator and forming gas flow meter are mounted on the base plate. The base plate is placed on the machine base which contains the variable voltage transformers for the nest and preheat oven, and also a temperature controller for the bonding nest. A microscope is used for the orientation of the bonding tip.

Machine No. 2 (Figure 3.14-3) is mounted on a base which contains all electric and pneumatic controls. This machine has three main operating sections: material inlet section (1), bonding section (2), and material outlet section (3). Machine No. 2 was designed after the operation of Machine No. 1 was tested; therefore, its design includes complete mechanization of material handling. Wafer bonded headers are supplied to Machine No. 2 loaded in the same magnetic trays as to Machine No. 1; however, 20 of these trays are loaded in one magazine. In the material inlet section the magnetic trays are discharged one at a time from the magazine into the track. From here the trays are transferred automatically to the bonding section. This section is the center protion of the machine and is identical with the bonding section of Machine No. 1. An X-Y-Z micro-manipulator, a bonding arm and viewing microscope are used in the same manner as in Machine No. 1. The nest design is identical with the nest in Machine No. 1. Two variable voltage transformers (for nest and preheat oven) and a temperature controller for the nest are mounted on the left and right front walls of the machine base. This machine has two dwell timers to accurately regulate dwell time when required. These timers are located on the left front wall of the machine base.

After placing a loaded magazine in the material inlet section, the following operations are performed automatically: transfer of the magnetic trays from the magazine into the track, index of the trays along the track, transfer of headers into and out of the bonding nest, and transfer of the magnetic trays with the completed units from the track into the receiving magazine. The operator controls the actual bonding operation by positioning the bonding tip with the small diameter gold wire to the appropriate stripes and internal leads. Therefore, larger tolerances of the piece parts supplied to the machines are permissible.

The function of the operator during the Wire Bonding operation is the same for both machines. The unit is viewed through the microscope and the bonding tip with the gold wire is positioned with the X-Y micromanipulator in proper relation to the point to be bonded. The Z-lever is lowered to perform the bond to the emitter stripe. Then the Z-lever is moved up to raise the tip and using the X-Y manipulator it is positioned on the post. Lowering the Z-lever makes the bond to the post. The Z-lever is moved up and the cutting device is actuated to cut the wire and form the tail which is required to make the next bond. The next bond is to the base stripe which is made after rotating the bonding nest 180 degrees. Bonding to the other post and cutting is the same as previously described.

IV Machine Development

As already mentioned, the principle of thermocompression bonding is used for both machines. One of the problems which had to be solved was the handling of the .0005-inch-diameter gold wire. In order to simplify the wire supply system it was decided to use precision made spools with conical shaft ends running in spring loaded jewel bearings. This design permits operation without motors, drives and all associated problems of motorized wire feeding systems.

The bonding tip used performs a dual function: one function is to guide the fine diameter gold wire; another function is to perform the bond. Originally attempts were made to prepare tips by swagging. They were made out of .063-inch-outside-diameter and .004-inch-inside-diameter stainless steel tubing, approximately 1/2 inch long, one end of which was swagged down to .0008 inch inside diameter. A piece of .002-inch-diameter tungsten wire was welded to this end and serves as the bonding anvil. The swagged tips prepared by this process had several disadvantages: the swagging operation was difficult to control, the tubing had a tendency to crack, the finish inside the tubing was not good. During wire bonding, dust particles or pieces of gold wire occasionally clog the bonding tip. Cleaning of the fine inside diameter was rarely possible.

All these difficulties were eliminated by the development of the split tip. This tip consists of two halves forming a tip with .063 inch shank diameter. These halves are brazed to flat plates which are aligned to each other with dowel pins. One-half of the tip has a groove which guides the gold wire. The lower end of this half carries the bonding anvil made of .002-inch-diameter tungsten wire. The other half serves merely as a cover for the groove. Figure 3.14-5 shows a disassembled split tip. Preparation of this tip is carefully controlled. The finish of the groove is approximately 20 micro-inches. If this tip is clogged it can be opened and cleaned without removing it from the machine.

Cutting the .0005-inch-diameter gold wire and forming a tail of proper length (.001 inch minimum and .002 inch maximum) for the succeeding bonding operation also represented a problem. An attempt was made to solve the problem by using blades only .002 inch thick. The performance of these blades was fair. More reliable operation was obtained by using blades .032 inch thick. The lower blade was ground 70 degrees to the cutting plane, the upper blade was ground 20 degrees to the cutting plane. With accelerated speed of the cutting operation, the 20-degree slope of the upper blade pushed the gold wire up into the bonding tip instead of forming a tail. To eliminate this condition it was necessary to break the cutting edge of the 20-degree slope (see Figure 3.14-6).

The original intention was to mechanize the positioning of the bonding tips containing the gold wire to the stripes and posts of the headers. Development work was initiated in two directions: first, to design an open loop positioning system with a high degree of accuracy, which repeats its motions within extremely small tolerances and, second, to develop methods to manufacture piece parts with tolerances tight enough to be used with such an open loop positioning system.

A cam operated positioning system was developed, capable of repeating within a tolerance of a few hundred thousands of an inch. In order to obtain this accuracy, precision ball bearings were used; in addition to this, the design provided spring tension in all strategic points to take up any play of the moving elements. The cams were provided with an extremely fine finish in order to eliminate all oscillations and erratic motions.

The manufacture of piece parts with the required tight tolerances proved to be uneconomical. Although it was possible to produce these piece parts, the high degree of accuracy required made them too expensive.

It was therefore decided to abandon the cam positioning system. As previously mentioned, the positioning of the bonding tip containing the gold wire in Machine No. 1 and Machine No. 2 is now controlled by the operator. This permits the use of piece parts with relatively wide tolerances without sacrifice of speed of operation.

In order to isolate all sources of shocks and vibrations from the bonding section of Machine No. 2, the members carrying the electric relays and the pneumatic valves are mounted on soft shock absorbers.

V Operational Problems

Difficulties experienced were of two types:

a. Bonding difficulties:

The bonding method used, with the continuous wire feed through the bonding tip, permits high rate of production if the operation is not interrupted. With good bondability of the units, these interruptions can be reduced to a minimum. If the bondability to the stripes or to the posts is poor, interruptions must be expected, causing a low rate of production and poor quality of the product. Poor bondability to the stripes was experienced when units or gold wire were not completely cleaned.

b. Header transfer:

As previously mentioned, the machines employ magnetic trays for header handling. These trays utilize the leads of the devices for holding; therefore, they are designed to be used with headers having straight, parallel leads, welded at the tips. Headers meeting these criteria were not always available. The operation of the machines with conventional headers without welded tips is satisfactory; however, headers with straight, parallel and tip welded leads must be used for optimum performance. For Machine No. 2, the variation of lead lengths should not be more than 1/8 inch.

Leads must be straight enough to avoid interference of adjacent headers on the magnetic trays. Headers having bent leads or lead length variation in excess of 1/8 inch cause difficulties.

Since the operation of these machines is entirely different from the manual wire bonding operation, training of the operators is most important. It has been found that operators adapt quickly to the new and more convenient operation.

Of major importance is the training of maintenance and set-up personnel. To attain the production goals set, the machine must operate continuously. Minor adjustments requiring a few minutes must be made when they are required. Although the necessity for these adjustments is infrequent, in view of the high-volume continuous operation, it is advisable to make them as soon as possible when they are required. It became apparent during the shop trial that the maintenance requirements of these machines are very low.

VI Machine Performance

The design rates of production of No. 1 Machine is approximately 150 units per hour and of No. 2 Machine approximately 300 units per hour. The design production rate for No. 1 Machine was reached, even exceeded during entire shifts. Machine No. 2, having mechanized material handling, is more vulnerable to material variation. For periods of several hours, the design rate has been reached and even exceeded. However, problems associated with materials supplied to the machine in combination with set-up problems have prevented maintaining this rate for an extended period.

Following are some of the factors which caused difficulties:

1. The leads of the headers were bent or exceeded length tolerances.
2. The internal leads (posts) had surfaces that were not suited for thermocompression bonding.
3. Stripes were too narrow and/or too close together.
4. Cleanliness of stripes and wire was at times not adequate.
5. Floor vibrations.
6. Shortage of trained maintenance personnel capable of making quick adjustments.

Test runs were made during the pilot run under conditions which minimized the above mentioned shortcomings: an improved operation was apparent. Most of the above factors were discovered and corrected during the pilot run.

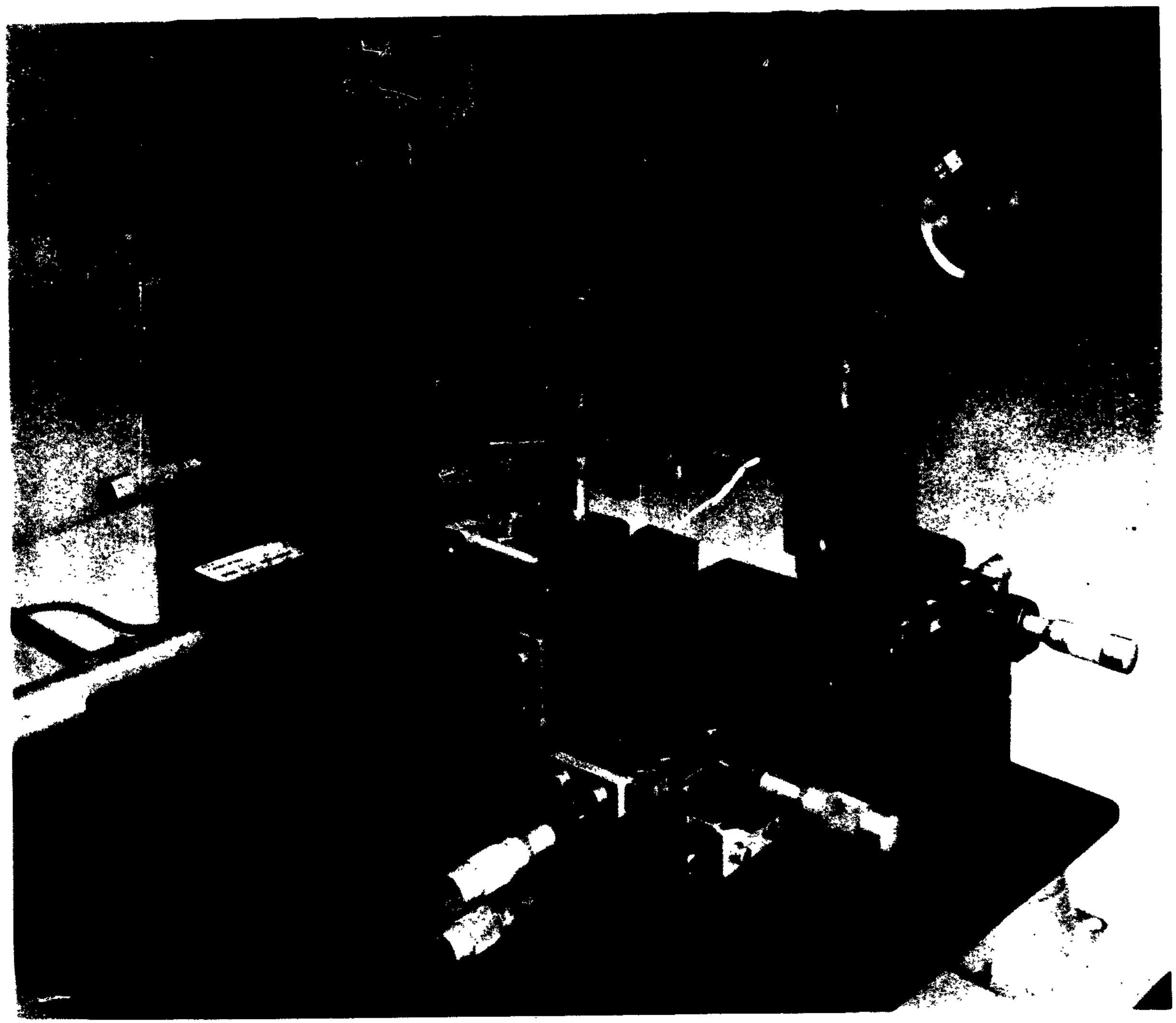
VII Evaluation

The physical operation of both machines is reliable and will require little maintenance. In spite of the small size of the parts to be bonded and accuracy required, only infrequent adjustments will be necessary; the machines have been operated for several days without adjustments. The operators have no difficulty learning to operate the machines; however, thorough training is required for maximum performance. Cleanliness of the parts to be bonded is important. When proper conditions were provided, the machines produced good, uniform quality.

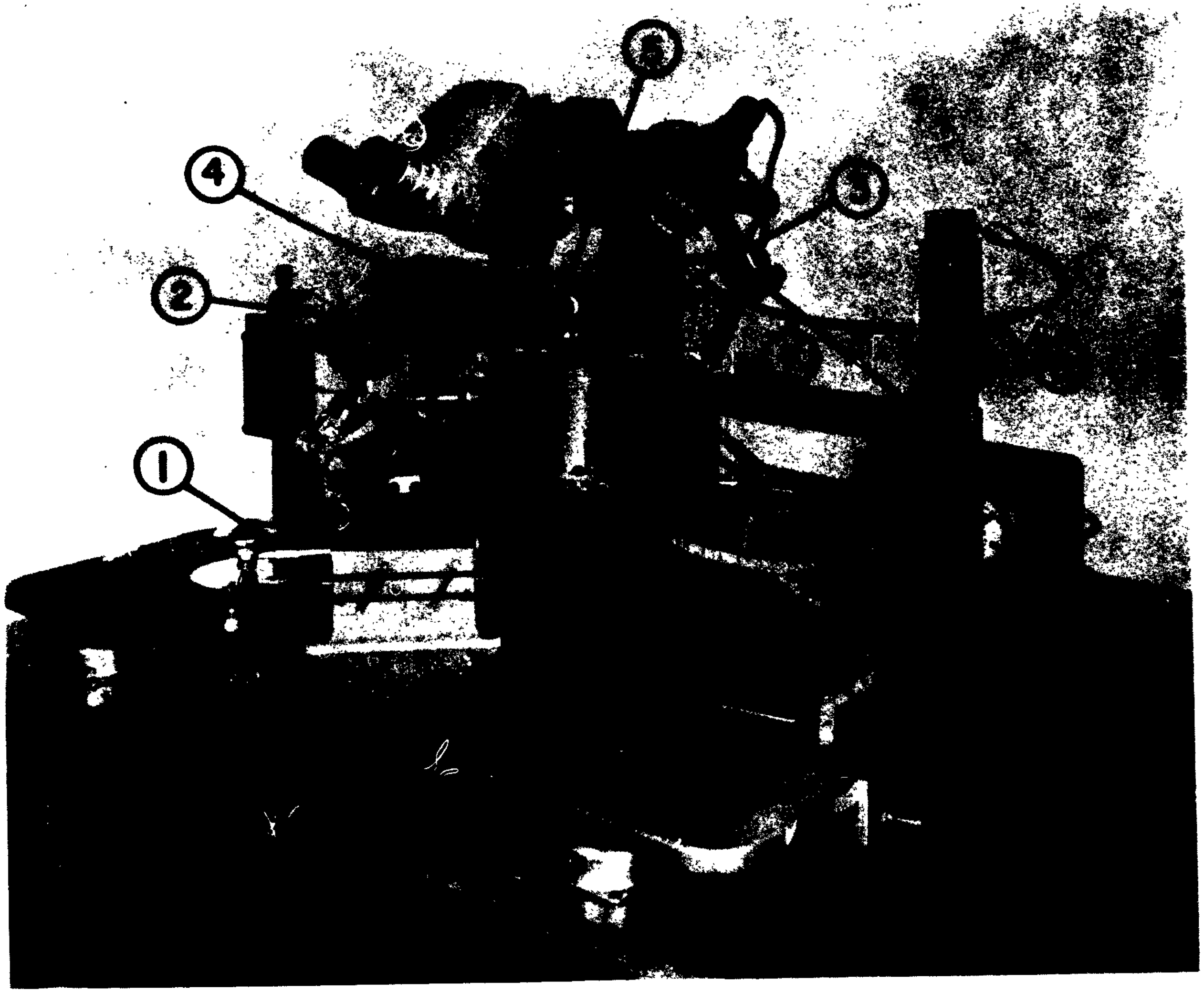
VIII Conclusion

Experience gained from the pilot run indicates that proper material and operating conditions must be provided in order to attain continuously the design production rate of the machines. Special emphasis must be placed on cleanliness and proper location of the machines in view of the floor vibrations experienced.

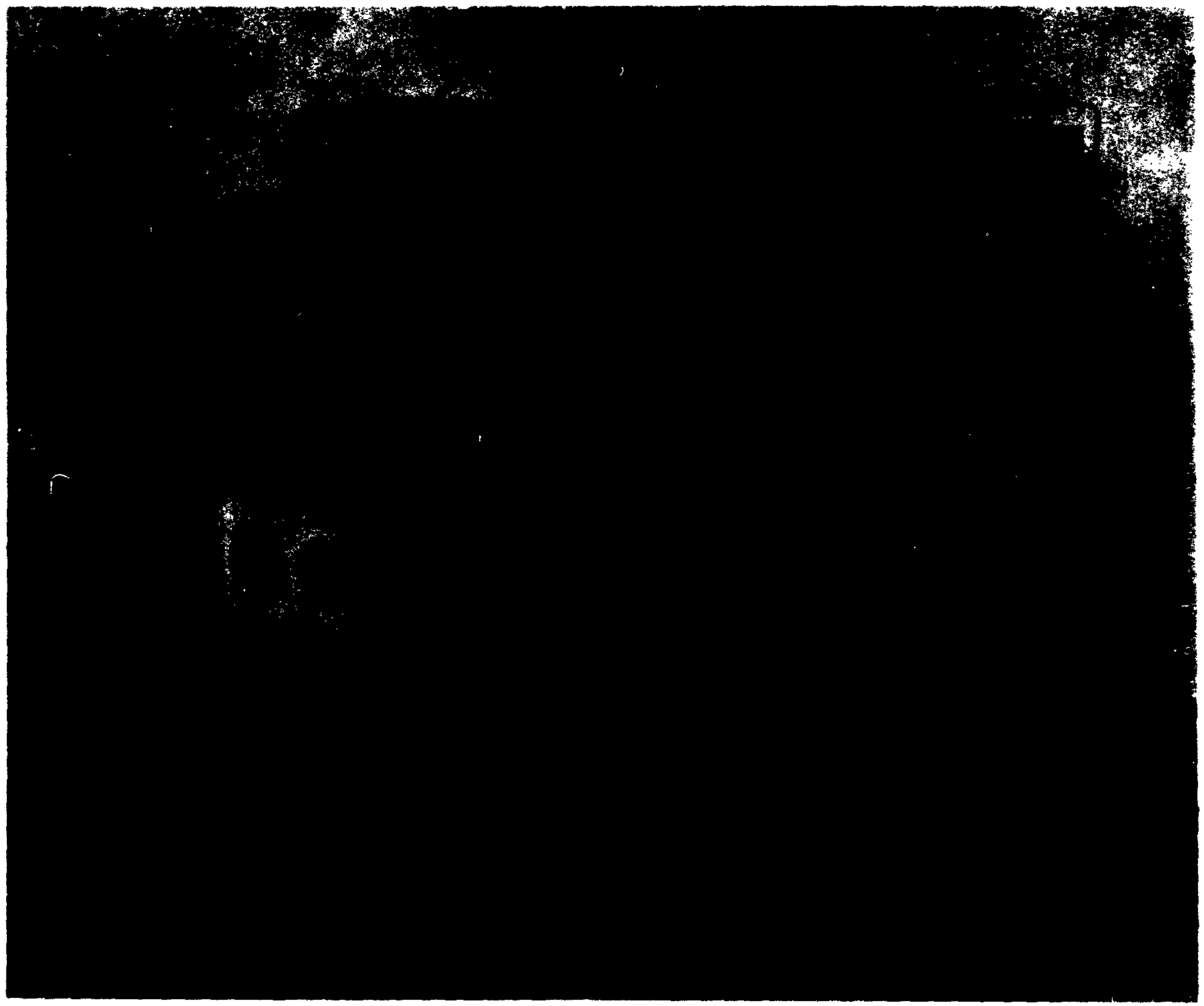
No mechanical difficulties were experienced in operation of the machines other than those caused by faulty headers. Cleanliness and reasonable uniformity of piece parts supplied to the machines is essential for trouble-free operation.



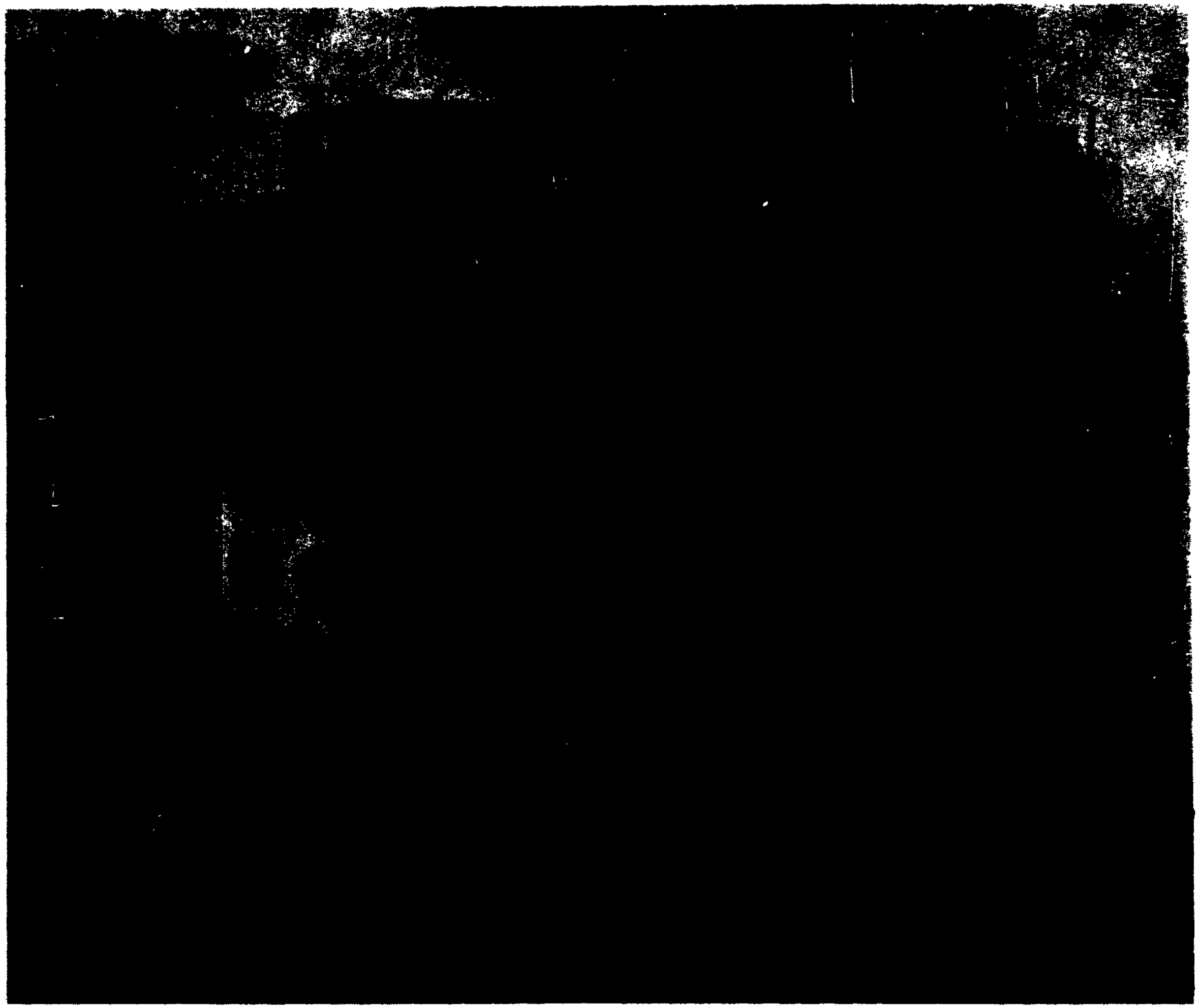
MANUAL WIRE BONDING TOOL
FIGURE 3.14-1



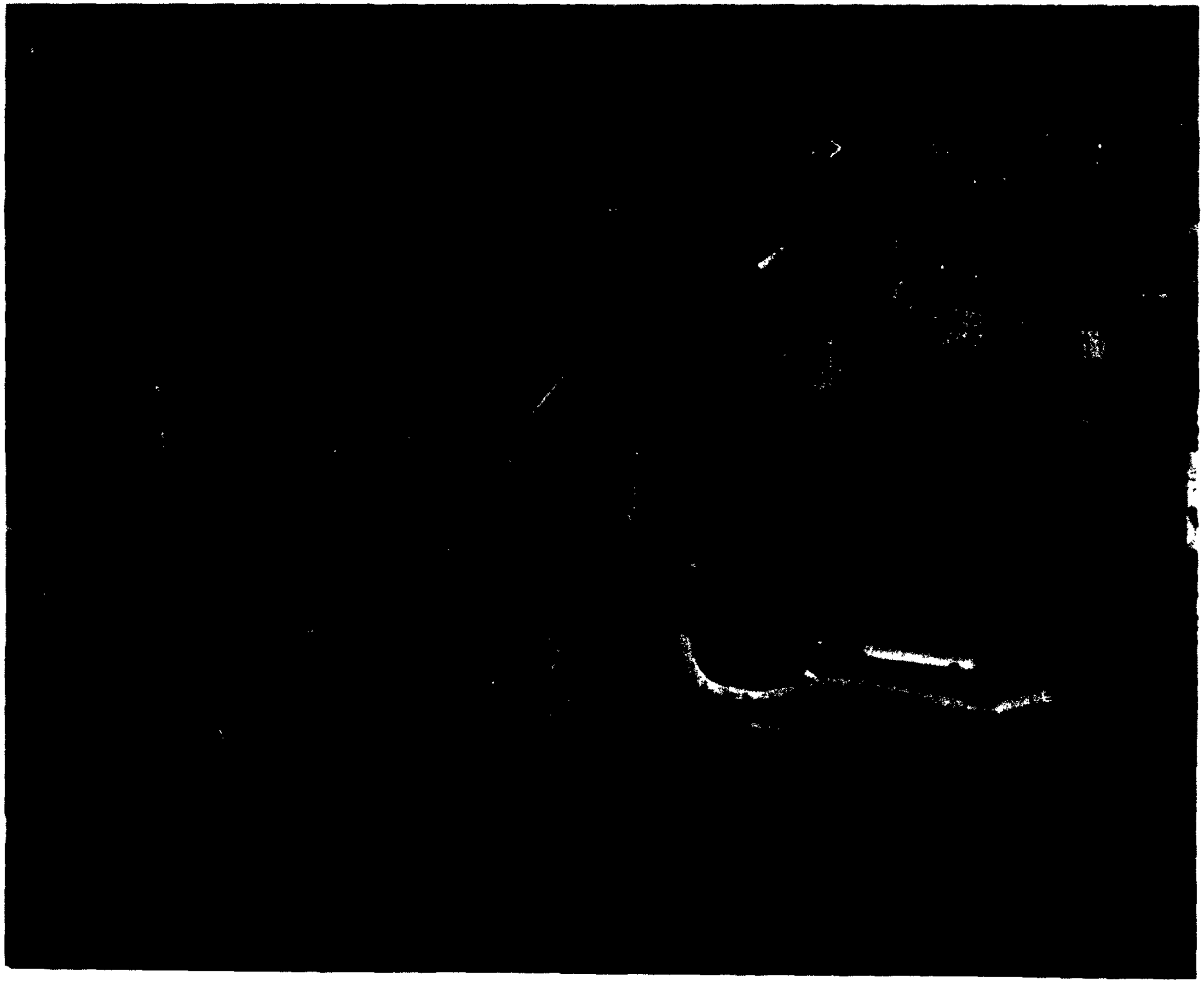
WIRE BONDING MACHINE NO. 1
FIGURE 3.14-2



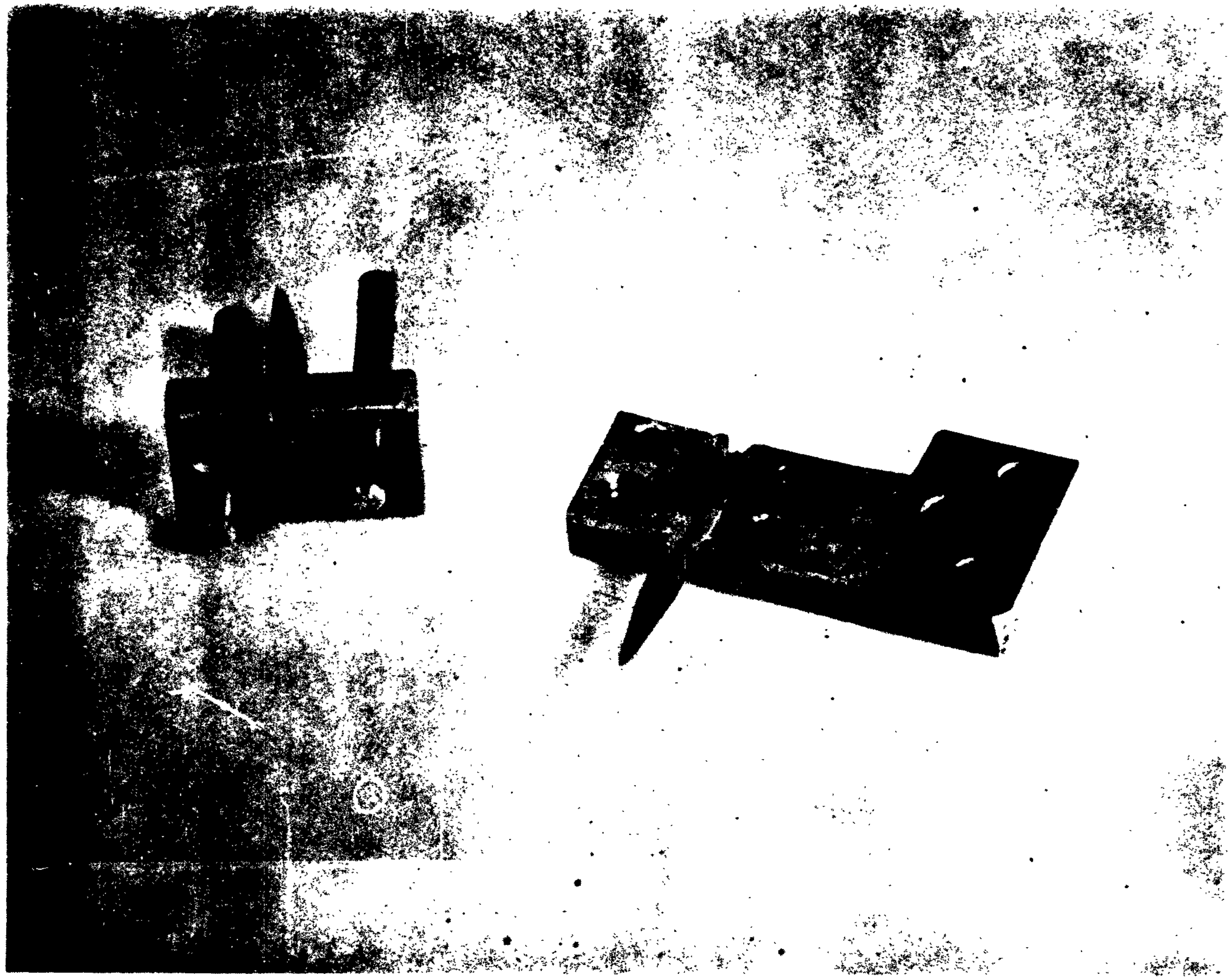
WIRE BONDING MACHINE NO. 2
FIGURE 3.14-3



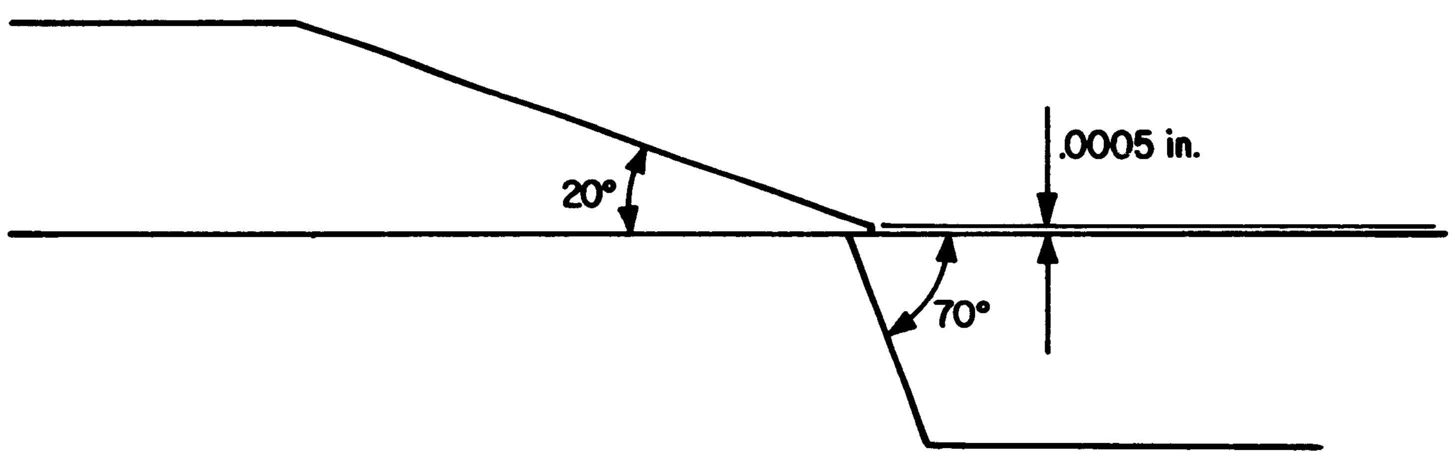
WIRE BONDING MACHINE NO. 2
FIGURE 3.14-3



BONDING STATION OF WIRE BONDING MACHINE NO. 2
FIGURE 3.14-4



SPLIT BONDING TIP USED ON WIRE BONDING MACHINES
FIGURE 3.14-5



WIRE CUTTING DEVICE ON WIRE BONDING MACHINES

FIGURE 3.14 -6

SECTION 3.15

FINAL CLEANING

J. H. Blewett

FINAL CLEANING

I General

The Final Cleaning operation is performed on the wire bonded germanium wafers immediately prior to encapsulation. Completed subassemblies are successively subjected to the following three timed operations: hot hydrogen peroxide wash, distilled deionized water rinse and acetone dip.

The original Final Cleaning Machine that was provided for these operations consists of four stations: an aligning station which properly aligns headers wafer side down contained in a magazine; two bubbler stations which contain 600 individual bubbling cups each and supply cleaning agents to each header in a magazine; and a hooded acetone dip station. Recently, the rinse station was modified so that the cleaning agent is supplied as distilled, deionized water, filtered and available in temperatures up to 200°F. At the rate of 600 units each run and a process cycle of 20 minutes, the output of the machine is 1800 units per hour.

The Final Cleaning Machine is dependable, easy to operate and should require a minimum of maintenance. In addition to these features, the machine possesses good repeatability which will improve the reliability of the product.

II Description of the Machine

The machine is a semi-automatic type in which the magazine is manually transported between the etching, rinsing and drying stations. Work moves from right to left through the three in-line stations. The machine occupies a space 5 feet deep by 17 feet long with access required in front, in back and around the left end.

The etching section consists of a structural steel table 30 inches wide and 5 feet long on which is mounted a movable trolley which carries a magazine filled with 20 trays containing 30 subassemblies each. The trolley is manually loaded in the center of the table, then moved to the right to engage the positioning station and locked in place. Turning an eccentric crank by means of a handwheel at the front of the station, raises the magazine and positions the 600 subassemblies in the magazine so that they will barely clear the etching bubbler assembly to the left side of this station. After positioning of the units, the trolley is manually moved to the left and locked in place over the bubblers. Figure 3.15-3 shows the magazine moving into position over the bubbles. Two circular storage tanks are located directly behind the etching station; the one on the right heats deionized water and the one on the left is used to mix the hot water and hydrogen peroxide. Both tanks are insulated and include heating coils, thermostats, pumps and necessary solenoid valves to recirculate or empty the tanks. The electrical controls, timers, temperature indicators and Solu-Bridges for monitoring water purity are mounted on a panel immediately above this station. The main disconnect switch is mounted on the right end of this station.

Directly beside the etching station is the rinsing station which is of similar structural steel construction, being 30 inches wide and 4 feet long. Mounted on the top of this section is a similar bubbler assembly and trolley on which the magazines are manually placed. Moving the trolley with the loaded magazine to the left will position the units over the bubblers for rinsing. A rectangular insulated storage tank and circulating pump is directly behind this station from which the bubblers get their treated rinse water.

The treated water from the rinsing bubblers drains by gravity to a holding tank from which it is pumped by a circulating pump through heat exchangers, a cooler, charcoal filter, resin demineralizer, microfilter, flow meter and a water heater back to the original rinsing storage tank ready for reuse. All this equipment, plus a still which produces distilled make-up water, is arranged in order behind the acetone drying station and extends 5 feet to the left of the drying station. This equipment is installed as shown on Figure 3.15-2.

Mounted on top of the rinsing water storage tank is a mercury float switch which protects the heating coil when the water level in the tank falls too low. This switch will de-energize both the 30-kilowatt water heater and the tank heater and also turn off the rinsing and circulating pumps when the water level gets too low. There are two thermal cutout switches acting as overload protection for the regular thermostats on both the mixing tank and the 30-kilowatt water heater to prevent damage to the machine.

Next in line is a third section, the acetone drying station which is constructed similarly and is about 30 inches wide by 3 feet long entirely covered by an exhaust hood. The rinsed units are placed on a trolley and moved by hand to the left over top of a tray filled with acetone. As the handwheel in front of the station is rotated 180 degrees, a cam lowers the units into the acetone. At the end of a timed cycle, a red indicator light is illuminated. The handwheel is then rotated back to its original position, raising the cleaned assemblies out of the acetone for removal to the next assembly operation. These three stations lined up from right to left occupy an area 30 inches wide by 12 feet long as illustrated in Figure 3.15-1. The distillation still, filters and heaters are not shown in this photograph since they were added later as modifications to the original machine.

The electrical controls are centered in two control panels, one over the etching station and the other over the heat exchangers and cooler at the left rear of the machine. The controls for the etching, rinsing and acetone stations have illuminated pushbuttons and indicator lights which are energized when the time cycles are completed. The controls for the treating of the distilled rinse water are on the control panel at the rear. This panel also contains the flow meter, pH monitor and recorder along with the Solu-Bridge and thermostat for controlling the water temperature in the 30-kilowatt heater.

The duties of the operator are to mix the hot water in the proper proportions with 30 percent hydrogen peroxide; set the timers for the proper etching sequence; load the magazine on the trolleys and start the various cycles. After the rinsing water temperature has stabilized, the operator can place a magazine on the trolley and start the cycle after adjusting the timers to the proper setting. After an indicating light indicates completion of a cycle, the operator must transfer the magazine to the next station.

Since the only moving parts on the machine are pumps, maintenance of the entire unit is kept to a minimum. Valve packing glands, pump seals and an occasional fitting leak are all the troubles that can develop. Thermometers, Solu-Bridges and pH Meters require periodic checking and recalibration which is done on a continuing basis. Clogging of the microfilter requires changing of the filter discs; however, a by-pass line is provided so that part of the flow can be directed around the filter when pressure becomes too high during a run. Thus, a run is not interrupted. Changing of these discs requires no tools and the filter head is readily accessible.

III Development

Originally, feasibility studies were made of the various methods for the emitter etching operation in order to determine the best engineering approach for the design of the Final Cleaning Machine. The original decision was to use a tape handling system which would be of a continuous-type rather than a batch-type machine using a system of trays. A change in wafer design from a mesa to a moat configuration, was made which affected the requirements that were placed on the final cleaning process. The thinking was then reversed and the batch-type handling system with a series of bubblers, one for each individual unit, was chosen. Design proceeded on that basis.

One questionable portion of the proposed design was whether or not heating of deionized water in stainless steel containers would reduce its purity to a point where it was not usable. Feasibility studies at various temperatures and time cycles were made, and it was determined that while the water purity was reduced, it met the standards necessary to produce clean acceptable units.

Since the bubblers are the heart of the machine, alignment of the 30 stainless steel tubes each containing 20 bubblers is of extreme importance in that all 600 bubblers must be level. This presented some difficulty during the early construction of the machine and one of the bubbler assemblies had to replaced. Other than this, the construction went forward without incident. One change made during the construction phase was the addition of interlocks in the cleaning, rinsing, and drying stations to eliminate operator variability. The interlocks work in conjunction with the cycle timers and regulate the length of time that the subassembly is exposed to the various etching and rinsing solutions. This feature should aid in creating a more uniform product.

IV Operational Problems:

At the beginning of the prove-in period, the most troublesome problem was the equalizing of the flow in the 600 bubblers. Each of the 30 bubbler tubes has its own regulating valve located next to the manifold. Experiments had to be run to determine the most efficient opening in the bubbler and to determine what pressure was required to supply each bubbler with the proper volume of liquid. Much of the trouble resulted from dirt and chips left in the system from the machining operations which clogged the openings. After an ample supply of liquid flowed evenly from all bubblers, it was discovered that the pan which collected the overflow was too shallow to carry all the water back to the drain, so it was redesigned. A tray with deeper sides and tapering toward the drain was provided to solve the problem.

It became apparent that the lead length varied so much that all units could not be immersed properly in the bubbling liquids. The units were positioned by pushing the tips of the leads against a flat plate in the positioning station on the machine. If the leads were long, the unit was too low and struck the bubblers, and if they were short, the unit was neither etched nor rinsed properly. Since the specification on the lead length allows a variation of 1/32 inch, even those units within specifications produce a variation in the height between the platform and the tray. For this reason, a new aligning fixture was developed which included a thin comb-type plate positioned next to the slots in the magnetic holding trays. When the units were loaded into the tray, this comb was under the flange of each header. By sliding the tray back against an adjustable stop, the units were raised up and their height above the tray was the same, within a few thousandths of an inch, since locating was done from the flange of the header instead of the tips of the leads. This permitted a much closer and more accurate setting of the magazine and assured proper exposure of the etching and rinsing liquids to each individual unit.

Operator training presented no problems as all controls are marked, and temperatures and liquid levels in the various tanks are indicated. Illuminated controls show immediately which circuits are energized and interlocked lights turn "on" at the end of each cycle as a reminder to the operator to remove the units.

V Performance

Initial runs made by splitting a lot of 620 units and using the regular 2N559 cleaning procedure produced a 70 percent yield for machine-cleaned units and a 72 percent yield for the manual control lot. Distribution for both lots were similar. Further checks were made with split lots totaling 1,000 units which were processed on the machine while using various combinations of rinse water temperatures - from room ambient to 180°F; various rinsing periods - from 50 seconds to 18 minutes, and cleaning cycles both with and without the hydrogen peroxide etch. These checks pointed to the fact that, while using a 15-percent hydrogen peroxide etch, the best yields result if an 18-minute rinse at room temperature follows the etch. If the etching is omitted, better results are obtained with a shorter hot water rinse. These runs were made over the machine without an alcohol or acetone dip; the units were dried by exposure for 5 minutes under an infrared heating lamp immediately after rinsing.

Shop trials conducted on the Final Cleaning Machine duplicating the current shop process, with a total of thirty-seven hundred 2N559 transistors, showed comparable yields.

VI Evaluation

The electrical and mechanical systems have proven very reliable. The pumps have operated continuously and have given no trouble whatsoever. The machine is easy to operate since all three process operations are timed by preset timers and the operator is merely required to adjust temperatures, flows, and transfer the magazine at the end of each timed cycle whenever a red light tied in with the interlock switches is turned "on".

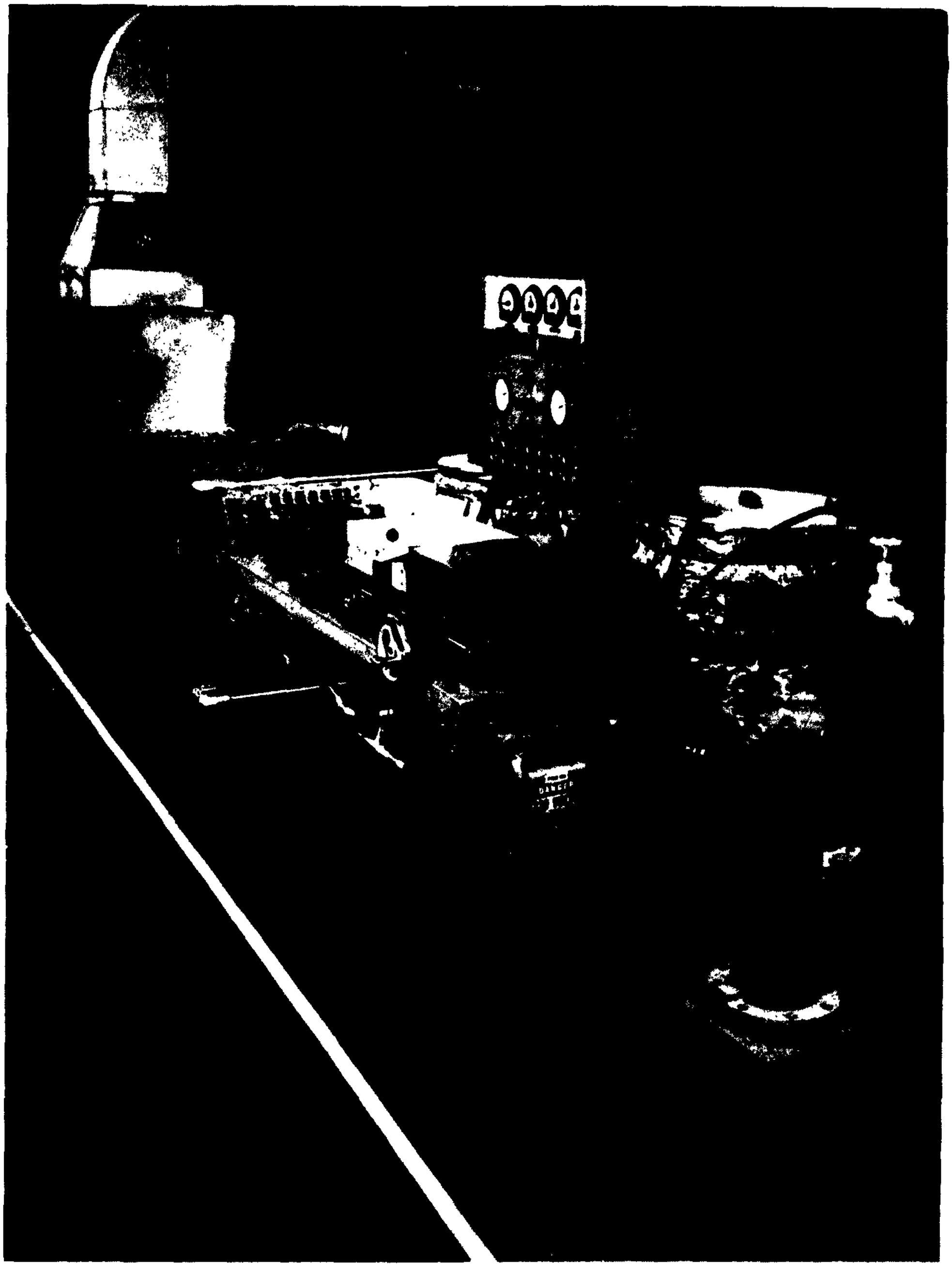
The addition of the filtering and heating system on the rinsing portion of the machine was prompted by the development of the hot deionized water rinsing and drying technique originally provided for the now deleted 2N560 Emitter Etching Machine, Contract No. DA-36-039-SC-81294. Use of a hot water rinse may also result in the elimination of the acetone dip as an aid to drying the units and, thus, the acetone dip station could be eliminated from the machine entirely.

A comparison of the mechanized and manual operation indicates that it takes 5 operators per shift, including loading and unloading the holders, to process 2000 units per hour; while one Final Cleaning Machine operator can process 1800 units per hour if the rinsing cycle remains at 18 minutes. With the possibility of greatly reducing the length of the rinsing cycle by filtering and heating the rinse water, the output for one operator on the machine could become substantially higher. Shop results show the yields of the units run over the machine are equal to those on the manual line.

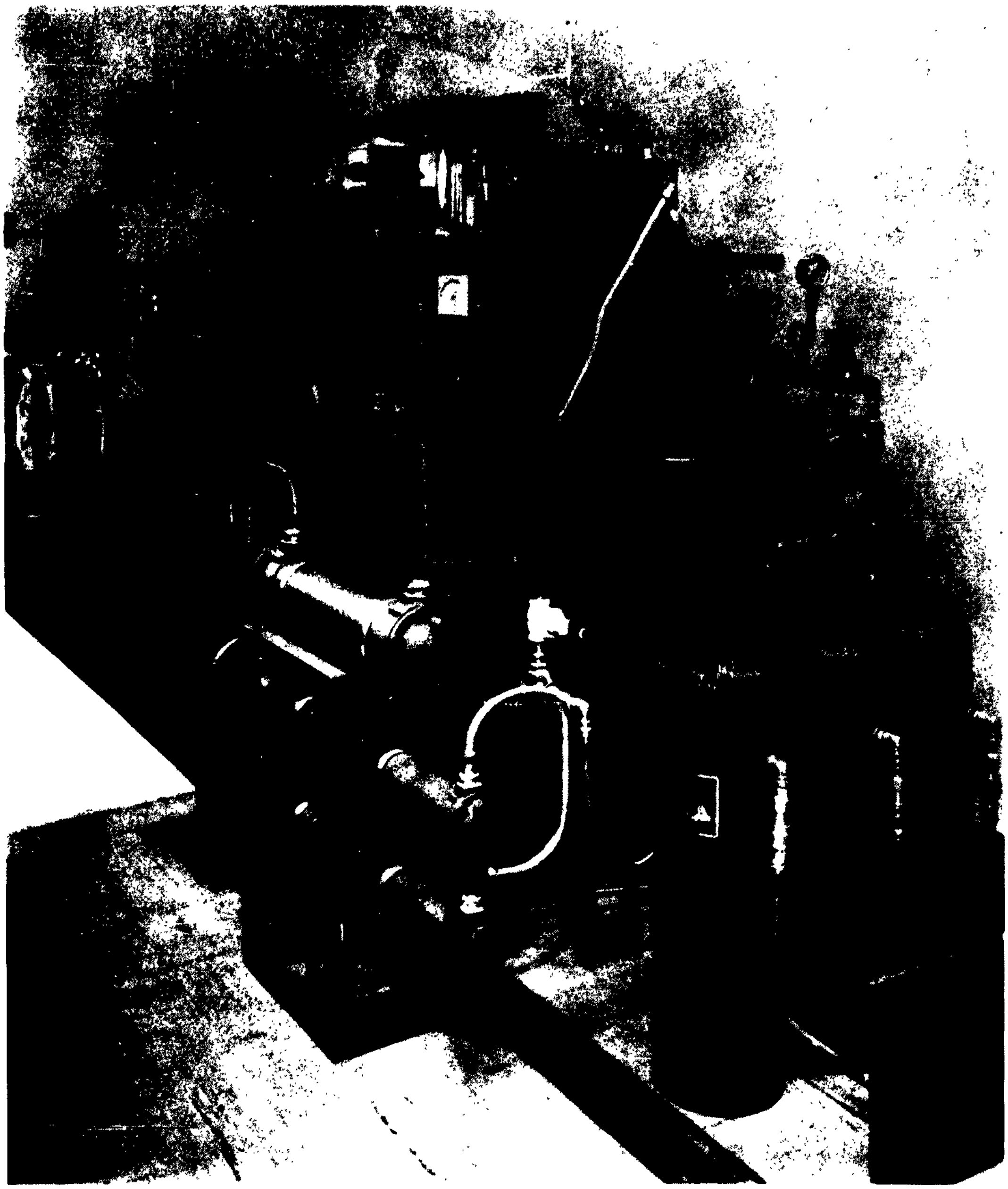
VII Conclusion

The Final Cleaning Machine has been proven-in and has run a controlled sampling of units for the pilot run. Additional shop trials will be started early in Phase 2 with 2N559 units.

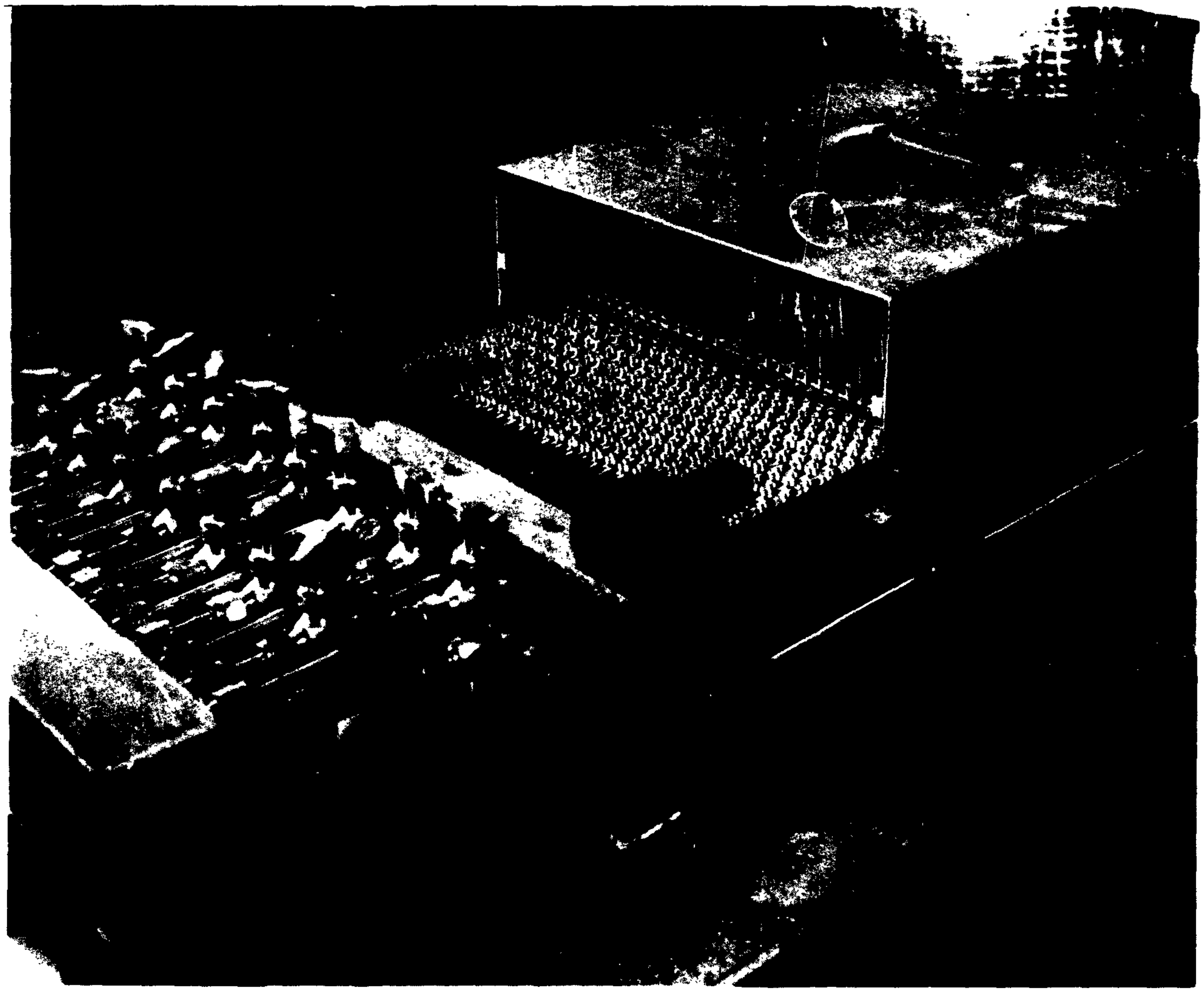
While this machine performs a batch-type operation, work can presently flow through without interruption at 1800 units per hour. Further experiments with hot deionized water rinsing could result in increased machine capacity by reducing the rinsing time. With its ease of operation, minimum maintenance, and timed cycles interlocked to assure repeatability, the Final Cleaning Machine has provided a simple, dependable and consistent method of performing the etching and rinsing operations.



ORIGINAL FINAL CLEANING MACHINE
FIGURE 3.15-1



MODIFIED FINAL CLEANING MACHINE - REAR VIEW
FIGURE 3.15-2



BUBBLERS ON FINAL CLEANING MACHINE
FIGURE 3.15-3

SECTION 3.16

CLOSURE WELDING

R. W. Ingham

CLOSURE WELDING

I General

The Closure Welding Machine will semi-automatically mate a can to a wired and bonded header and hermetically seal the parts with a resistance weld. This machine was built to mechanize manual welding operations of TO-18 devices, to increase production rates, to improve welding yields and reliability, and to conserve helium gas. This machine is of the rotary index type and is used in conjunction with controlled atmosphere, low humidity bake ovens. The ovens, while physically attached to the machine, are not a part of it and will not be covered in this report. The index turret and the machine work area have been totally enclosed and sealed from the room ambient to maintain a controlled atmosphere during the encapsulation and welding of the device. This machine can provide a suitable atmosphere for, and weld, any TO-5 package with only minor modifications to the welding electrodes.

A need for this machine was emphasized by the anticipated high volume Nike Zeus production requirements and the need to conserve helium. The development, construction, and prove-in of this machine have been brought to a successful conclusion.

II Machine Description

The basic purpose of this machine is to provide a number of small controlled atmosphere enclosures within a larger controlled atmosphere work area. Both of these areas must be able to maintain low moisture ratios. The large outer enclosure houses the necessary mechanized equipment and work area for handling the cans and headers while the small inner enclosures, of which there are 16, constitute the welding fixtures. These welding fixtures are of a 2-piece construction, a lower and upper section, to facilitate loading the piece parts into nests in the welding fixture. After the piece parts have been loaded into their respective nests, the welding fixture is mechanically closed; however, the piece parts remain separated until after the fixture has been flushed with clean dry gases. During welding the inner enclosure is flushed with nitrogen gas to prevent discoloration of the can. After welding a nitrogen flush removes the gaseous by-products resulting from the welding operation and exhausts them to the atmosphere.

To seal the machine compartment from the ambient atmosphere, the center post of the index unit was modified and three pairs of low pressure oil seals were installed. The surface of the centerpost was ground and polished to a 6 micro-inch rms finish. A welded stainless steel enclosure was mounted on the machine base to totally enclose the work area from the ambient. Access to the work area by the operator is provided by two sets of arm holes. These openings are fitted with commercial rubber sleeves and surgical gloves. Parts are moved to and from the work area through two double-door air locks, one of which connects the work area to the outer atmosphere and the other connects with the baking ovens.

A 20-KVA Taylor Winfield Resistance Type Welder is located to the rear of the machine. Silicone rubber diaphragms provide the seal between the welder electrodes and the controlled atmosphere enclosure without restricting their movement.

Constant monitoring of the moisture content of the work area is available through the Electrolytic Water Analyzer mounted in the control console (Figure 3.16-3). A 24-hour chart recorder coupled to the

Electrolytic Water Analyzer provides a permanent record of moisture content for evaluation studies. Provisions have been made so that moisture of the individual gases in the work area or oven area can be monitored. A recirculating gas dryer is used to supply the low moisture ambient used in the ovens and work area. This dryer is not considered to be a part of the Closure Welding Machine. The control console houses all machine controls, flow controls, valves, relays, power transformers and timers. Storage area for electrodes and related parts is located in the lower section of the console.

Figure 3.16-1 pictures the machine as covered by this report and shows the general arrangement of the 16-station Swanson Erie Turret Index Unit (1); the stainless steel controlled atmosphere enclosure (2); and the 20-KVA Taylor Winfield Resistance Welder (3). The welder controller which is located adjacent to and behind the welder on this photo is partially visible through the openings in the framework that supports the welder. A panoramic view of the welder, console and baking ovens (Figure 3.16-2) shows the arrangement of the complete installation. The recirculating gas dryer mentioned earlier is located to the right of the bake oven just beyond the range of the camera.

Figure 3.16-4 is a view of the welding fixtures and gas distribution system as seen by the operator. (Item numbers are for the purpose of identification only.) Sixteen 2-piece welding fixtures are located on the face of the index turret by means of a pilot which is not visible. The upper half of each fixture is mounted on two round shafts that insure positive alignment of upper and lower halves of the welding fixture. A fiber nest (2) surrounds the lower electrode (3) and locates the header until the upper electrode (4) lowers the can into place over the header.

Each welding fixture is connected to a valve body (5) which houses three "on-off" type valves. The valves are operated by cam plates (6) that are attached to the fixed centerpost of the index machine. Each valve controls the flow of one gas or a mixture of gases fed to the flushing chamber of the lower electrode holder. An electrode resetting device (7) checks and resets the height of the upper electrode after each welding cycle to insure the proper location of the can during the flushing period prior to welding. Figure 3.16-5 illustrates the flow pattern of the gases.

The sequence of operations is shown on Figure 3.16-6. The numbers indicate the index positions; the unload position has arbitrarily been chosen as number 1.

The duties of the operators consist of: starting the machine by pressing the start button, loading the cans and headers into the welding nests, and unloading the finished devices and placing them into racks. Raw materials and finished product are supplied to and received from the operators through the airlocks by material handlers. The duties of the operator also include replacing the welding electrodes when so instructed.

III <u>Development - Process</u>

A process development program which has resulted in the Closure Welding Machine was initiated by building a large outer dry-box, a small inner dry-box or enclosure, and integrally connected bake-out ovens. With such an installation, the process could be varied in order to study it from a mechanization viewpoint. The double dry-box concept had a number of advantages: (1) A substantial gas savings could be realized as a result of the small volume of the actual welding chamber which can be flushed and exhausted continuously to the outside atmosphere during the welding cycle; (2) the smaller volume of the welding chamber permits relatively hazardous gases such as oxygen to be used with a minimum of danger.

The dry-box and welding mock-up were used to conduct a number of welding experiments using various quantities and combinations of gas. The results obtained from the first series of experiments were very disappointing. The moisture content of the dry-box atmosphere during these experiments was from 50 to 500 ppm (parts per million). These experiments were conducted over a 2-hour period. Before any more tests were run, the dry-box leak rate was decreased so that the moisture content could be held at 30 to 80 ppm in the machine compartment and 2 to 3 ppm in the welding fixture. As a result, devices purged and welded in the improved dry-box met all device specifications. The work described above was extensive and was done over a period of approximately one year. Welding electrode shapes similar to those used on the manual line were used.

In addition to the development work done on welding, a considerable amount of time and effort was expended in providing a getter material suitable for mechanized transistor manufacture. This portion of the development is discussed in detail in the report on the Can Getter Assembling Machine. Early concepts of enclosing the device considered the possibility of combining the Can Getter Assembling Machine and the Closure Welding Machine into a single complex machine. This approach was abandoned in favor of two separate machines due to the complexity of such a machine and its large size when connected with its bake oven. It should be noted that since the time the decision was made not to combine the two operations, there have been two major changes in the gettering concept.

Machine development included the development of a workable welding fixture and electrode design, and the development of the extensive and complex gas handling and monitoring system. The welding fixture, which was chosen, houses and locates the welding electrodes. A fiber orienting ring surrounds the electrode and locates the header. O-ring seals isolate the chamber and minimize leakage to and from it during gas flushing and welding. Copper welding electrodes with "Elkonite" facing and shapes similar to those used on the manual line were used and proved successful.

One of the principle requirements of a transistor is that the ambient sealed inside the can must be free of all foreign matter. This requirement precluded the use of lubricants inside of the dry-box. The operation of sliding parts without lubrication was handled by selection of a ceramic filled bearing of "Teflon" having a very low coefficient of friction.

Dimensional stability of the material was found to be satisfactory after being held in a low moisture atmosphere from 24 to 36 hours. For this reason the allowances for press fits of the bushings must exceed those used for metals by about 5 to 10 percent. Bore diameters should allow no clearance to a few ten-thousandths of interference. It was further found that shafts used with this type material should have a minimum hardness of 55 Rc and a surface finish of 8 micro-inches rms or better.

IV Operational Problems

After the machine had been installed and all electrical connections made, the dry-box enclosure was flushed with plant nitrogen having a known moisture content of 2 to 3 ppm and put under approximately 1/2 pound per square inch gage pressure. A flow rate of 60 cubic feet per hour was used to flush the dry-box. All gases were expelled to the atmosphere by bubbling them through a 1-inch column of glycerin. During this period the moisture content of the dry-box atmosphere was approximately 100 ppm. Increasing the nitrogen flow rate to 80 cfh (cubic feet per hour) had little, or no, effect on the moisture ratio. With the dry-box under pressure, all joints, seams, doors, and fasteners were checked for leaks and appropriate corrections were made wherever necessary. With a flow rate of 40 to 60 cfh of plant nitrogen, a moisture ratio of 20 to 30 ppm could be maintained in the dry-box enclosure. The enclosure was then connected to a General Dynamics Recirculating Gas Dryer and, with a recirculating gas flow rate of 300 cfh, the moisture ratio of the dry-box was brought down to less than 5 ppm.

Early prove-in revealed that a very slight misorientation of the header prior to being mated with the can could cause the electrodes to be damaged during assembly. To aid in orienting and assembling the can to the header, a device was installed which causes the upper electrode containing the can to rotate while the can is being lowered over the header. To further protect the electrodes from being damaged due to improper mating of the can and header, a safety switch was installed which senses the condition and prevents the welder ram from lowering to the weld position and the welder from firing. Since the force on the can and header prior to welding is very light, improperly seated devices will not be damaged when the welding cycle is voided. A closer study of this problem revealed that header misorientation was due primarily to the force being exerted on the header by the magnet located in the upper electrode. It was found that as the electrodes approached each other the header was being lifted from its nest and out of the locating slot so that header orientation was lost. The problem was solved by reducing the force of the magnetic field until it was just enough to hold the can in the upper electrode without influencing the header.

A number of minor problems presented themselves as prove-in continued. It was found that after the lower electrode contacts and welding contacts had been redressed, they were no longer seating properly, consequently, producing bad welds and severely pitted contacts. This problem was corrected by providing additional clearance between the lower welding ram and a fixed stop located on the machine. On occasion it was found that the welded devices tend to adhere to the lower electrodes. A special tool was designed which allows the operators to remove these units without damaging the units or the electrodes.

V Performance

The Closure Welding Machine was among the last of the PEM machines to be built and installed under this phase of the Contract. At the time of this writing, shop trial runs have been started and are progressing satisfactorily. Approximately 150,000 devices have been welded on the machine. Peak net operating rates of over 800 welded devices have been obtained on several occasions. The machine was originally designed around a 5-second cycle (720/hour) but was changed to a 3.33 second minimum (1080/hour) during the formal design phase. The machine is usually operated on a cycle that would yield a gross output of 1000 units per hour.

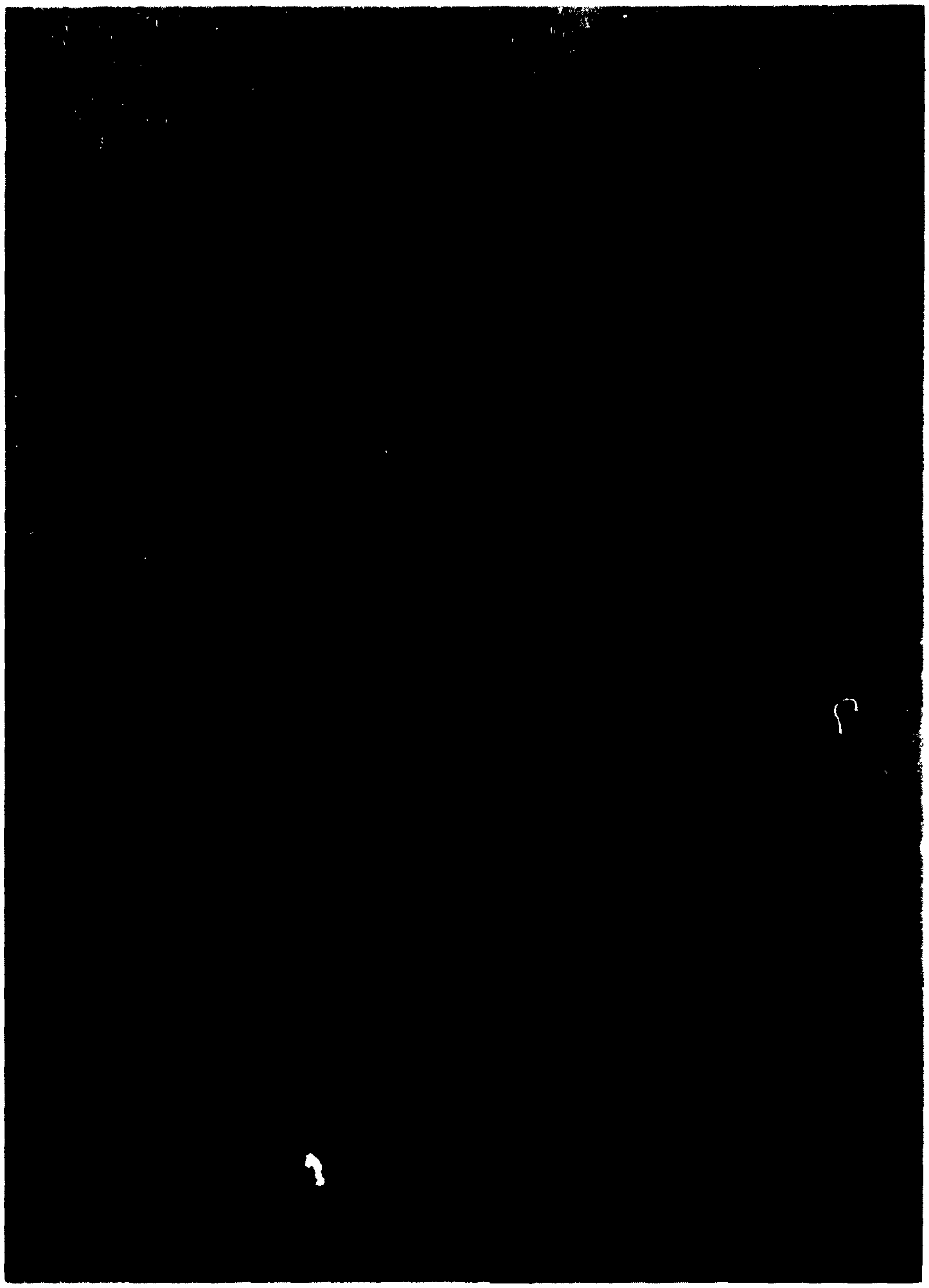
Material handling in the machine has required more time than originally anticipated and has decreased the production by an estimated 100 units per hour. Figure 3.16-7 is a plot of production rates obtained when operating the machine during a portion of the shop trial run phase. Those points on the graph that fall far below the average can be traced to difficulties connected with removal and replacement of electrodes.

The electrode problem has been traced to arcing between electrode and electrode holder. This arcing is due to a locking screw not being tightened properly or coming loose due to vibration. The problem of electrode arcing will be eliminated by a modification to the electrode holder.

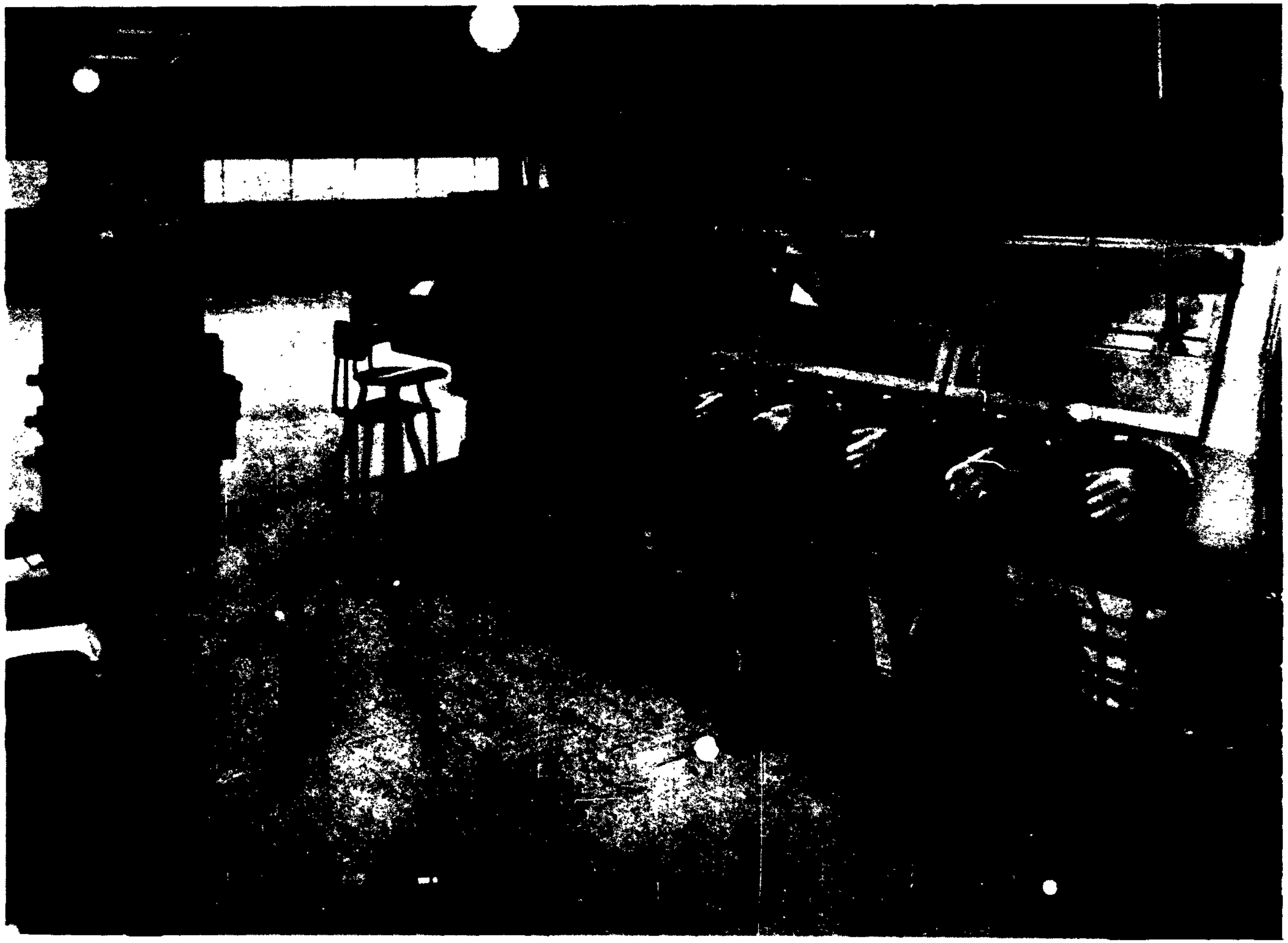
VI Conclusion

The Closure Welding Machine has demonstrated that it can produce units capable of meeting all device specifications. Nitrogen gas consumption has been reduced to approximately one-fourth of comparable manual methods and helium consumption has been reduced to approximately one-sixth of comparable manual methods. In addition, a safe and reliable method for handling oxygen has been provided.

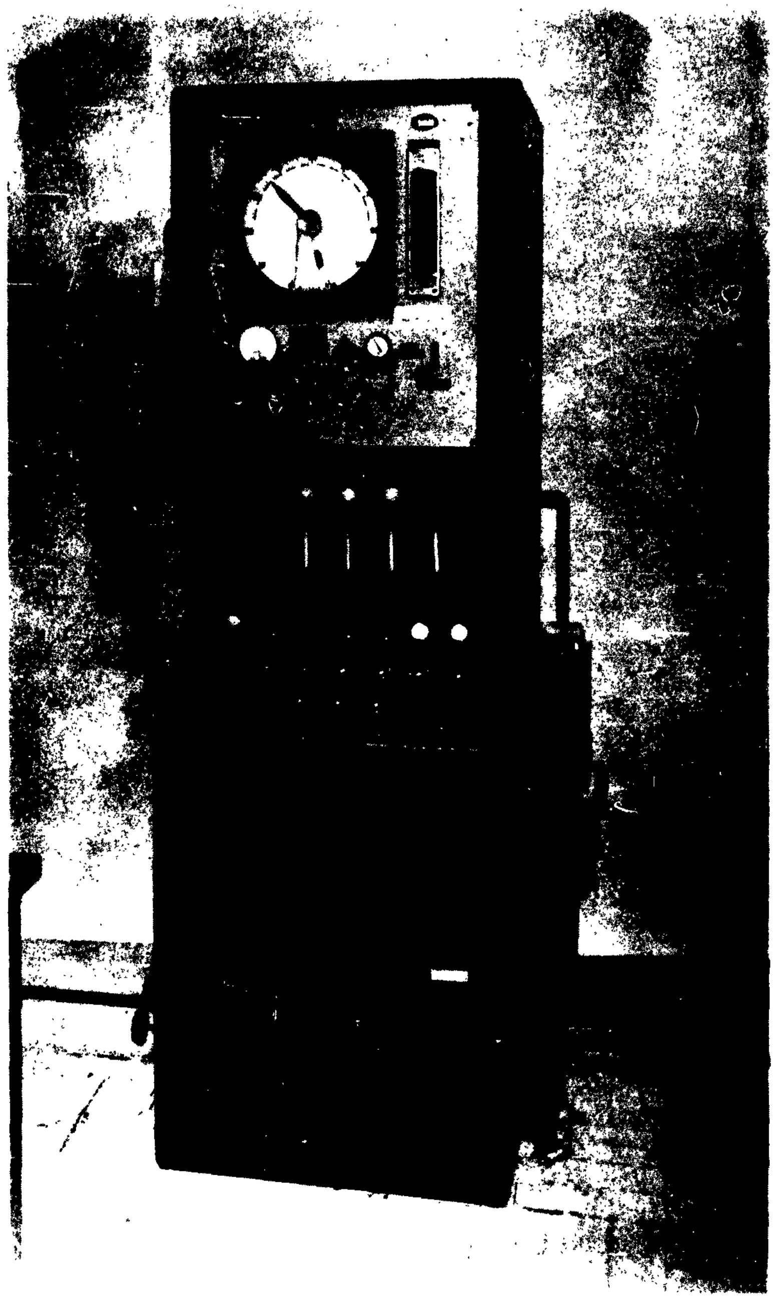
During prove-in and shop trial runs, it became apparent that an improved method for material handling, in and out of the machine and associated equipment, could result in an increase in production as a result of reduced material handling time. This problem is presently being studied and should be eliminated during the Phase 2 portion of the Contract.



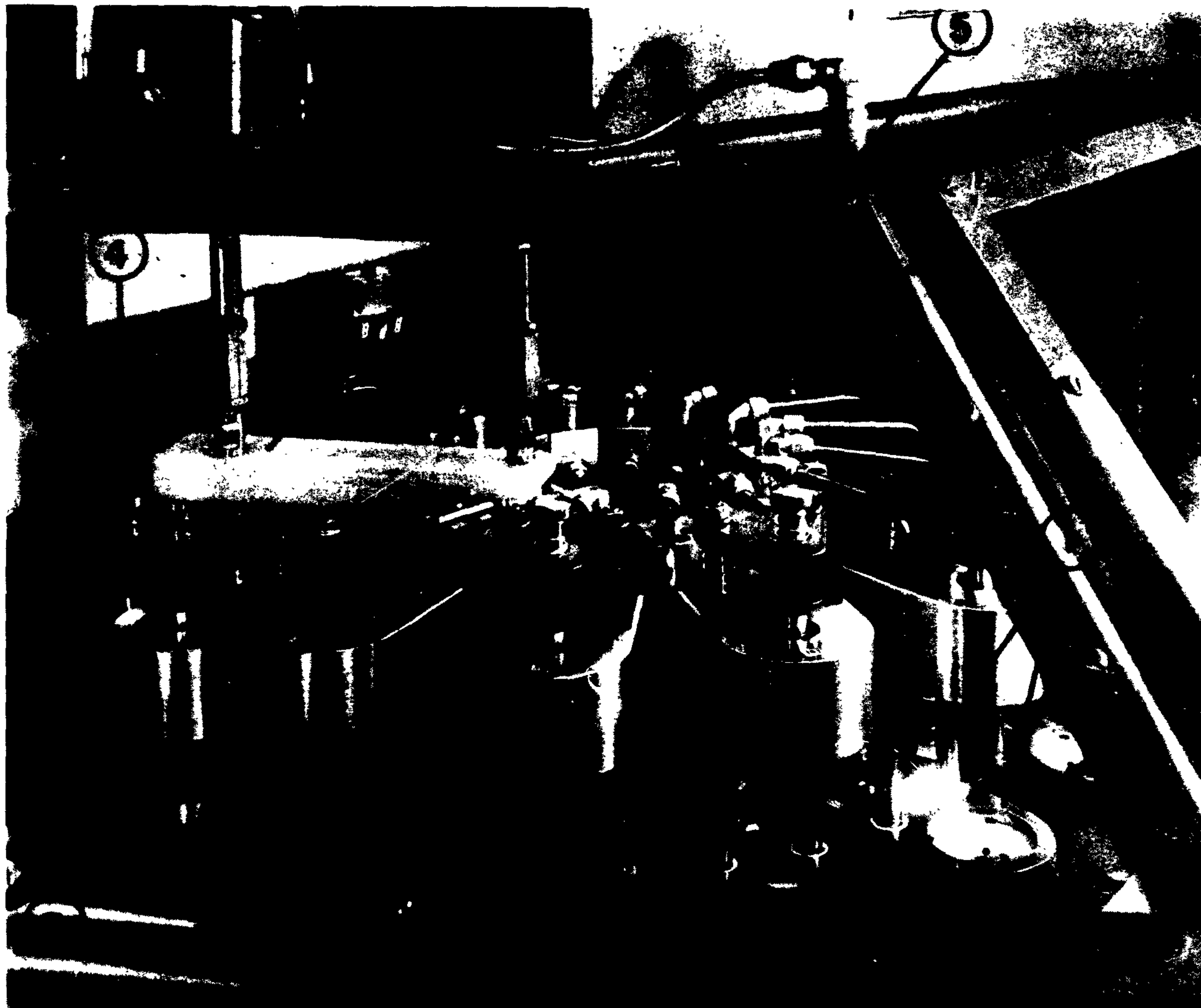
CLOSURE WELDING MACHINE
FIGURE 3.16-1



CONTROLLED ATMOSHPERE BAKE OVENS ATTACHED TO
CLOSURE WELDING MACHINE
FIGURE 3.16-2



CONTROL CONSOLE OF CLOSURE WELDING MACHINE
FIGURE 3.16-3



WELDING FIXTURES AND GAS DISTRIBUTION FOR
CLOSURE WLEDING MACHINE
FIGURE 3.16-4

FLOW PATTERN OF GASES IN FIXTURES OF CLOSURE WELDING MACHINE PRIOR TO WELDING

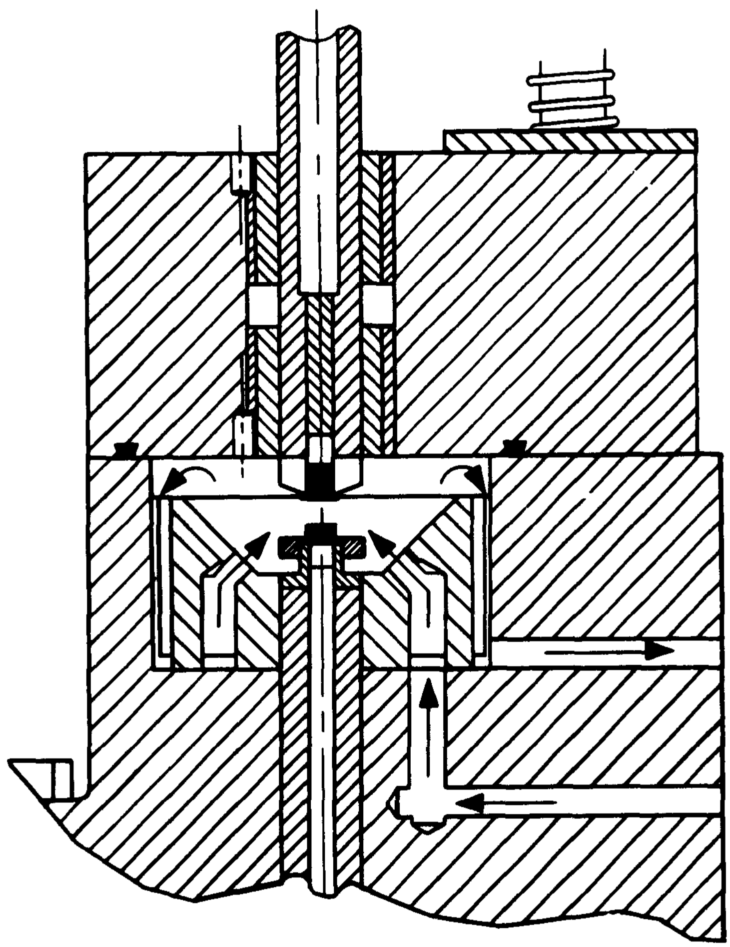
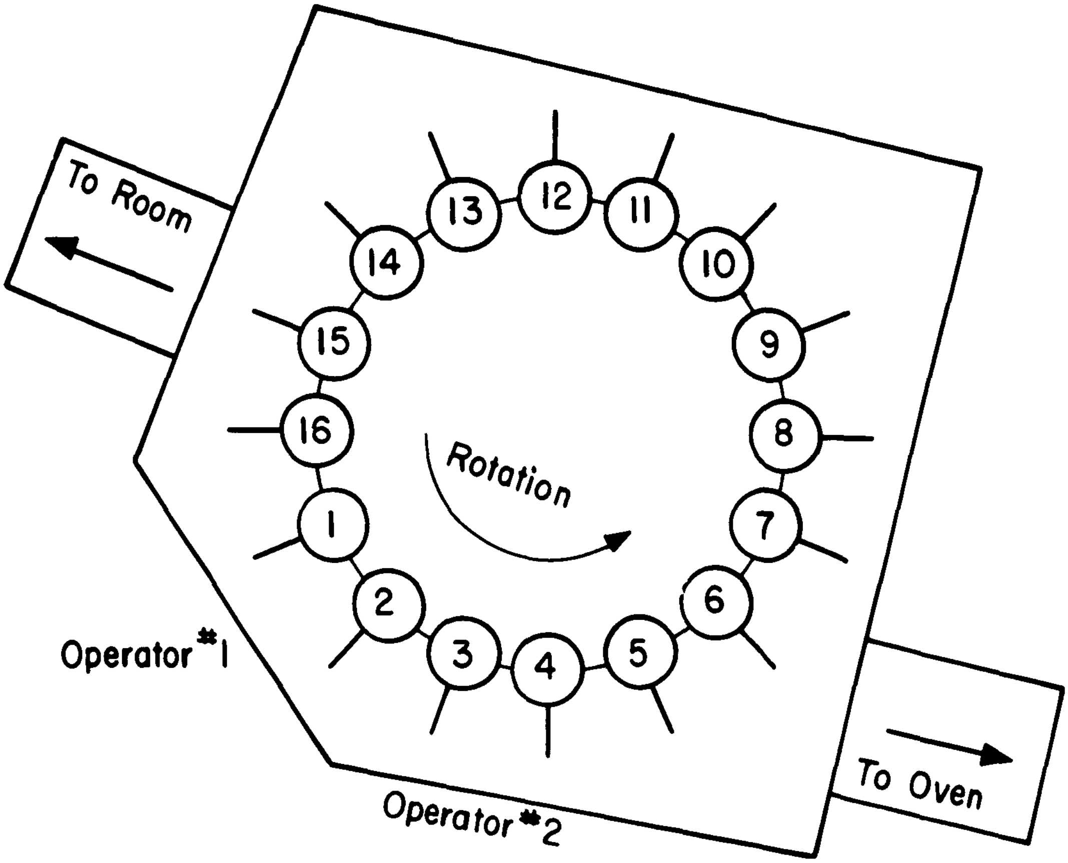


FIGURE 3.16-5

SEQUENCE OF OPERATIONS ON CLOSURE WELDING MACHINE



1. UNLOAD FINISHED UNIT
2. LOAD GETTERED CAN IN UPPER ELECTRODE

3&4. LOAD HEADER IN LOWER ELECTRODE

5,6&7 CLOSE WELDING FIXTURE HOLD ELECTRODES OPEN

8,9&10 FLUSH WITH DRY N_2 GAS

11 FLUSH WITH ENCAPSULATION AMBIENT

12 CLOSE ELECTRODE (CAN IS NOW LOCATED ON HEADER) AND WELD.

13. FLUSH WITH N_2 TO REMOVE WELDING RESIDUE

14,15&16 OPEN WELDING FIXTURE.

FIGURE 3.16-6

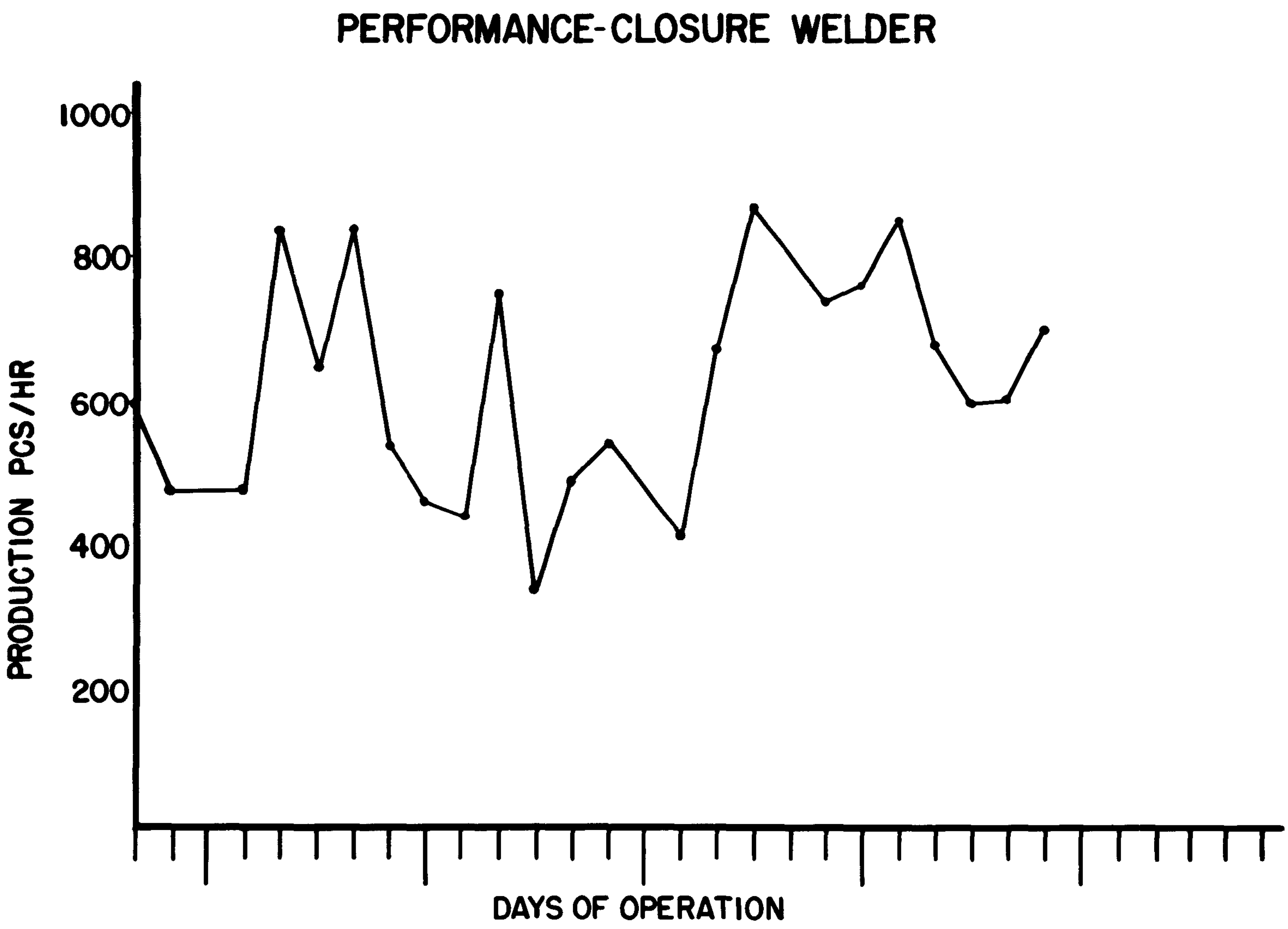

PERFORMANCE-CLOSURE WELDER
1000
800
600
400
200
PRODUCTION PCS/HR
DAYS OF OPERATION

FIGURE 3.16-7

SECTION 3.17

CARD LOADING

C. R. Fegley

CARD LOADING

I General

The Card Loading Machine, which is attached to and synchronized with the Testing and Date Stamping Machine, forms transistor holders by attaching the 2N559 transistors to a belt with heat sealable tape. As the belt leaves the machine, it is cut into individual transistor holders or cards which are fed and accurately positioned in the Testing and Date Stamping Machine at 900 units per hour. After testing, the holder becomes part of a unique shipping package, which enables the customer to automatically test the transistors while they are in the shipping belt and also accurately positions them for automatic removal from the transistor holders.

By attaching the Card Loading Machine to the Testing and Date Stamping Machine, one operator can monitor the test set and supply the Card Loading Machine with material. Material handling has been minimized; floor space was conserved, and high production rates were realized with this approach.

II Description of Machine

The Card Loading Machine was designed to attach to and become part of the Testing and Date Stamping Machine. It occupies 17-1/2 by 22 inches of floor space at one end of the Testing Machine as shown in Figure 3.18-1. The Card Loading Machine consists of the following stations itemized below:

1.	Belt Supply	Item 1, Figure 3.17-1
2.	Air Operated Punch Press	Item 3, Figure 3.17-4
3.	First Heat Sealable Tape Supply	Item 1, Figure 3.17-4

4.	Second Heat Sealable Tape Supply	Item 2, Figure 3.17-4
5.	Lead Spread	Item 5, Figure 3.17-4
6.	First Heat Seal	Item 6, Figure 3.17-4
7.	Second Heat Seal	Item 8, Figure 3.17-4
8.	Tape Indexing	Item 9, Figure 3.17-4
9.	Transistor Pick-up	Item 1, Figure 3.17-3
10.	Rack Indexing	Item 2, Figure 3.17-3
11.	Combing	Item 3, Figure 3.17-3
12.	Cutting	Item 1, Figure 3.17-5
13.	Transfer	Item 2, Figure 3.17-5
14.	Card Guide	Item 3, Figure 3.17-5

Black electrical cardboard, heat-sealable tape, and transistors mounted on magnetic racks are fed to the Card Loading Machine. A belt is punched from the .022-inch-thick by 1-7/8-inch-wide coil wound black electrical cardboard (Item 2, Figure 3.17-1). Later after the transistor is attached to the belt, it is cut into cards. The transistors are attached to the belt by two heat sealable tapes supplied in coils (Items 1 and 2, Figure 3.17-4). The heat sealable tape and the card material or belt feeds have detectors which will stop the machine and indicate which detector stopped the machine. When a magnetic tray containing transistors should be fed into the machine, a detector will ring a single stroke bell every cycle until a new tray is started.

After the card material is inserted into its compartment, it is fed into the punch station which punches indexing holes and notches as indicated at "4" in Figure 4.17-4. From the punch press the punched card material is fed to the lead spread station and its first heat seal station. At this point the transistor is placed on the card material.

The magnetic handling trays containing transistors are indexed into position where the transistors are picked up, rotated, and locked by the chuck and placed into position for lead combing. A comb is then positioned and locked over the leads near the header as shown in Figure 3.17-3, Item 1. After the comb is closed, it is moved along the leads to guide them into the lead spreader. The leads are spread as they are pushed into the lead spreader by the forward motion of the pickup chuck. After the transistor is pushed into the lead spreader, it is attached to the card material with the 3/8-inch-wide heat sealable tape by the first heat seal station.

After the first heat sealing operation, the card material containing transistors attached with the narrow strip of heat sealable tape as shown in Item 7, Figure 3.17-4 is advanced to the second heat seal station where the 5/8-inch-wide heat sealable tape is fastened to the card material. The card material containing the attached transistors is then fed over the indexing drums and guided to lower it to the level of the test holders of the Testing and Date Stamping Machine. The card material is indexed to the cutting station where it is cut into 1-1/8-inch-wide cards as shown by Item 4, Figure 3.17-5. The cut card falls onto a platform from which it is guided onto a test holder of the Testing and Date Stamping Machine which is then indexed through the test stations.

The Card Loading Machine is driven by the camshaft of the Testing and Date Stamping Machine, and therefore, is at all times synchronized with it. The card index and all positioning mechanisms for transistor feeding are cam operated. The balance of the machine is air operated and controlled by a sequence timer connected to the driveshaft of the Card Loading Machine.

III Machine Development

A simple, inexpensive transistor holder was required for testing the 2N559 transistor. The holder after testing would become part of the package for shipment. It had to firmly hold the leads of the transistor in a fixed manner, yet the transistor had to be easily removed from the holder without any residue on the leads. Many materials and configurations were investigated for the holder as well as methods for fastening the devices to the holder. A simple holder meeting all requirements was designed consisting of punched black electrical cardboard for the holder material and two strips of heat sealable tape for attaching the transistor to the holder.

Originally a Card Loading Machine was designed and built for attaching the 2N559 transistor automatically to the transistor holders. This machine would automatically remove a material handling rack containing 30 transistors from a magazine, feed it into position where 10 transistors at one time would be attached to card material that was punched one station earlier. The transistors were attached to the card material with heat sealable tape and then wound on a large reel. The reel containing approximately 1,500 transistors became the input to the card cutting and feeding mechanism that was attached to the Testing and Date Stamping Machine.

The Testing and Date Stamping Machine was constructed several months before the original Card Loading Machine was scheduled to be completed and in order to prove it in, card-mounted transistors were needed. A simple hand loading tool was constructed to supply the card-mounted transistors at 500 devices per hour.

The original machine and the hand loaded tool were both designed to process transistors with 3-inch leads. Before the original Card

Loading Machine was proven-in, the lead length was changed to 1-1/2 inches. Through a feasibility study it was found that it would be more economical to build a new Card Loading Machine than to convert the original Machine.

The new Card Loading Machine was designed and built incorporating the simplicity of the hand loading tool; the cutting and transferring functions of the card feeding mechanism of the Testing and Date Stamping Machine, and a simple automatic transistor handling system for inserting the transistor into the lead spreader. All of the required operations were included in one compact machine, occupying slightly more floor space than the original card cutting and feed mechanism. With the new approach, savings were achieved through less material handling, less floor space and less storage space.

IV Machine Performance

The Card Loading Machine was built from partially detailed drawings, engineering sketches and layouts. As the parts for the machine were completed, they were installed and proven-in, leaving few problems for final prove-in. Transistors rotating as they were picked up by the chuck and buckling of the card-mounted transistor as it was transferred into the Test Set were the only problems that had to be overcome.

The transistor rotating on pickup was due to bends in the leads and axial misalignment of cans and leads. While proving-in the Card Load Machine approximately 10 percent of the transistors were lost due to bent or damaged leads which were caused by rotation of the transistor at pickup. When it became apparent that transistors with straight leads would not be available in the immediate future, a new chuck was designed that would engage the small tab on the transistor and lock it in the proper position. With the newly designed chuck and transistors with reasonably straight leads, almost no transistors are lost in the pickup and combing operations (less than 1 percent).

As the belt containing the mounted transistors was cut into cards prior to transferring into the Testing and Date Stamping Machine, the card would occasionally bounce out of position. The card would then strike a portion of the frame and buckle as it was transferred to the Testing and Date Stamping Machine. This problem was easily solved by modifying the transfer track.

The shop trial was started with the integrated Card Loading and Testing and Date Stamping Machines running at approximately 500 devices per hour. It was at this time that a new chuck was required to increase the yield. After the new chuck was installed, the machine speed was gradually increased to its present speed of 900 transistors card loaded and tested per hour.

V Evaluation and Conclusion

The Card Loading Machine can be broken down into several basically simple mechanisms which should require very little maintenance. Through the use of nylon bearings, the machine can be run with little or no lubrication. The ease with which it can be loaded permits an inexperienced operator to reach production speeds in a minimum of time. While running production, it was found that a clutch, new cams for higher speed operation and a multiple index to accomodate the new magnetic handling rack would be desirable.

No provision has been made to disengage the Card Loading Machine from the Test and Date Stamping Machine. This is desirable to enable the operator to hand load transistor test standards into the Test and Date Stamping Machine without cutting the black electrical cardboard in the Card Loading Machine.

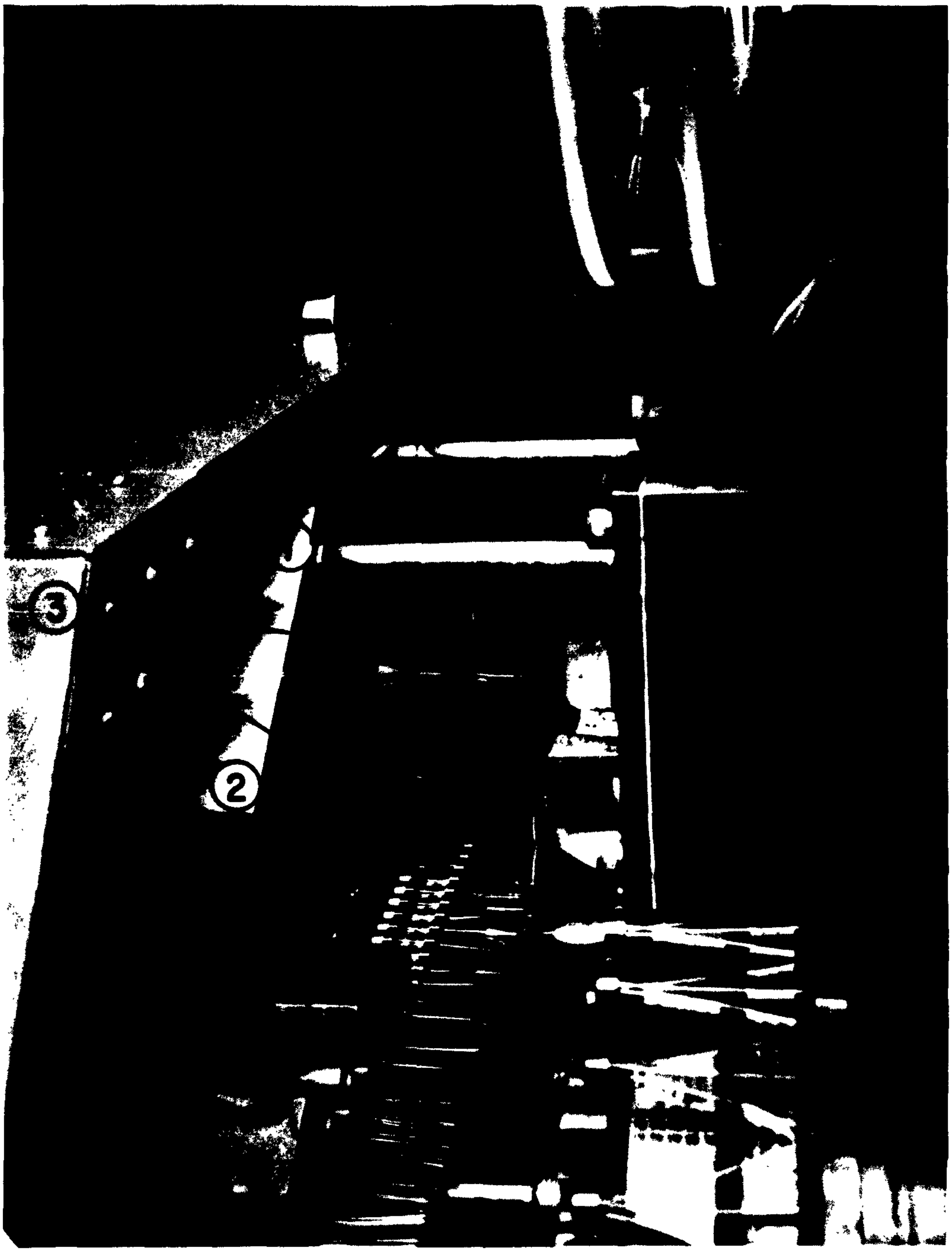
A uniform displacement curve has been used for designing the cams in the machine. These cams operate satisfactorily at speeds up to 900 units per hour. For smoother operation at higher speeds, cams using a modified trapezoidal acceleration curve should be installed.

On every magnetic handling tray that is fed into the Card Loading Machine, there are 1-1/2 empty spaces at each end of the tray. This in effect means that 3 blank cards are fed into the Test Set when each tray containing 30 transistors is loaded. Originally the machine was designed to use a magnetic handling tray that had one-half of an empty space on each end. To eliminate feeding empty blanks into the Test Set, an air operated extra index was included in the original design. The stroke of this mechanism is too short to permit skipping the three blank spaces at the joint of two magnet handling trays. An air operated device with a longer stroke should be installed to eliminate the insertion of blanks into the test set.

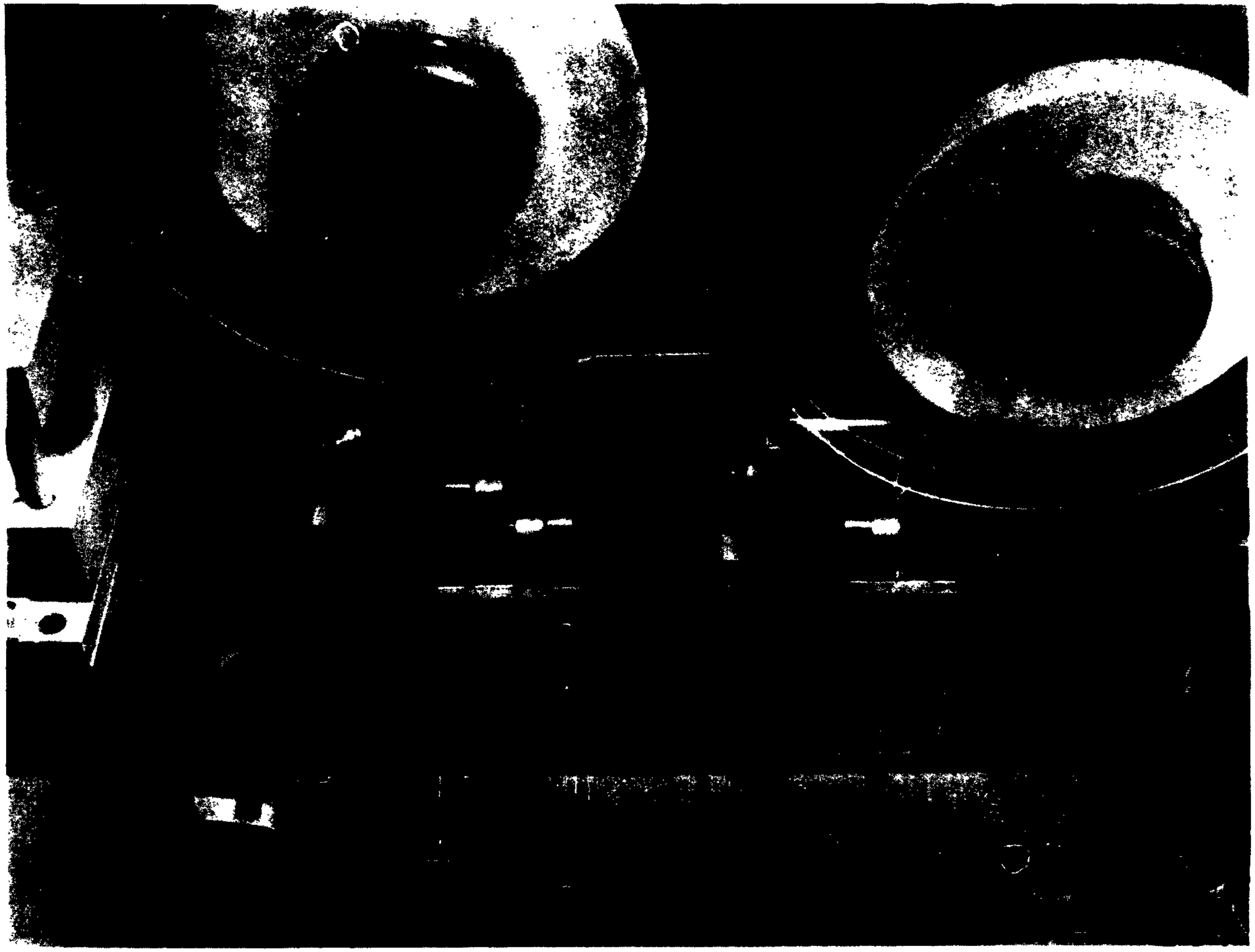
With the addition of a clutch, new cams and a multiple index, this machine will be a trouble-free production machine capable of feeding units into the Testing and Date Stamping Machine at its maximum speed.

CARD LOADING MACHINE VIEWED FROM LEFT
FIGURE 3.17-1

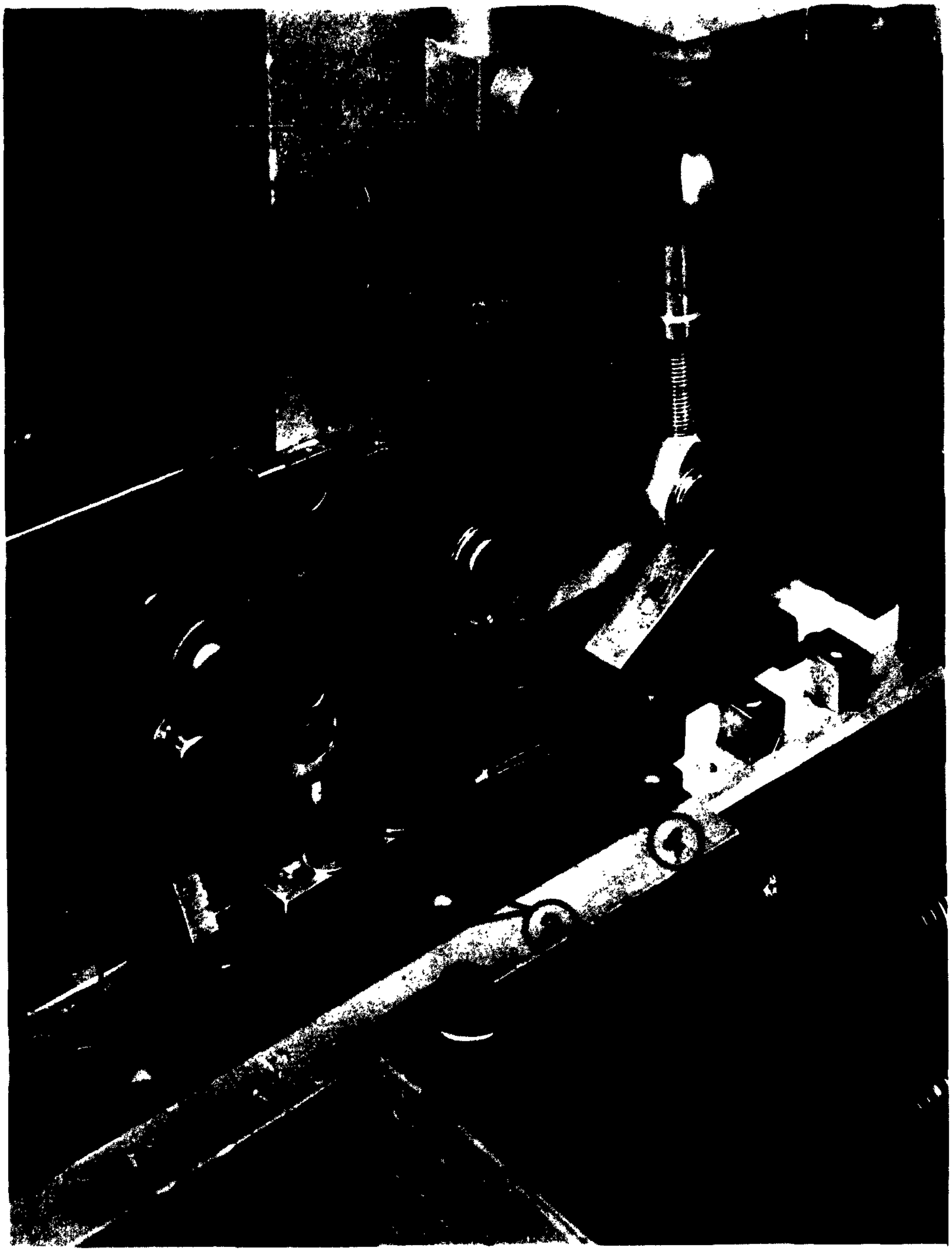
CARD LOADING MACHINE VIEWED FROM RIGHT
FIGURE 3.17-2



LEAD COMBING ON CARD LOADING MACHINE
FIGURE 3.17-3



TOP VIEW OF CARD LOADING MACHINE SHOWING ASSEMBLY STATIONS
FIGURE 3.17-4



CARD LOADED TRANSISTOR BEING TRANSFERRED INTO
TESTING AND DATE STAMPING MACHINE
FIGURE 3.17-5

SECTION 3.18

TESTING AND DATE STAMPING - 2N559

D. H. Lockart

TESTING AND DATE STAMPING - 2N559

I General

The Testing and Date Stamping Machine provides capability for performing all Group A electrical tests on P-N-P Germanium Type 2N559 Transistors in accordance with MIL-S-19500/152A and for stamping the top of the transistor can with a three digit acceptance date. Tests are performed on a go no-go basis with rejection following the first test failed. Only good devices remain on the test line to be stamped with the acceptance date and subsequently unloaded into a "good unit" bin.

The tests performed by this machine are listed below in the order in which the tests are made:

1. Emitter - Base Cutoff Current - I_{EBO}
2. Emitter - Base Breakdown Voltage, Collector Base Open Circuited - BV_{EBO}
3. Collector - Base Cutoff Current - I_{CBO}
4. Collector - Emitter Breakdown Voltage, Emitter Base Short Circuited - BV_{CES}
5. Base - Emitter Voltage, Saturated - V_{BE} (sat)
6. Collector - Emitter Voltage, Saturated - V_{CE} (sat) at I_C = -10mAdc and I_B = -0.4mAdc
7. Forward Current Transfer Ratio Common Emitter - h_{FE}
8. Collector - Emitter Voltage, Saturated - V_{CE} (sat) at I_C = 050mAdc and I_B = -1.5mAdc
9. Pulse Response - Storage Time - t_s
10. Pulse Response - Fall Time - t_f
11. Pulse Response - Rise Time - t_r

All test modules were designed and constructed by the Western Electric Company with the exception of the module for measuring the three pulse response time tests listed. Commercially available equipment was purchased and modified to provide this capability. A commercially available index table was procured to transport the transistors during testing and date stamping. All mechanical tooling and associated attachments were constructed by the Western Electric Company.

Prior to availability of this machine, 2N559 transistors were tested on a series of manual test sets. In all cases devices were manually inserted into a test socket and selected tests were programmed by manually depressing a series of keys. D-C tests were performed on one test set and pulse response time tests were performed on a second. Approximately one hundred devices could be tested on all parameters per hour using the manual equipment.

In addition to the slow testing rate, other problems were associated with this process. Devices were destroyed due to improper insertion into the test socket and to grounding of static charges, induced on the operator, through the transistor. Operator attention and judgment was continually required to make the many decisions necessary in reading and interpreting test readings. In view of the shortcomings of manual testing, it was apparent that improved testing reliability could be gained by providing mechanized equipment.

The output of the Testing and Date Stamping machine is a completed 2N559 transistor meeting all Group A requirements of the applicable specification. It is mounted on a black card material as shown in Figure 2-7. The transistor can easily be removed from the card either manually or automatically for insertion into circuitry. It is in a fixed orientation which cannot vary since the device would have been rejected during testing if the collector and emitter leads were interchanged.

II Description of Machine

The Testing and Date Stamping Machine, shown in Figure 3.18-1, is operated in conjunction with the Card Loading Machine described in Section 3.17. The latter machine mounts the transistor to be tested on a belt of black electrical cardboard, cuts the belt into individual cards, each card holding one transistor, and inserts the card into one of 36 test holders of the Testing and Date Stamping machine. The operations performed by the Card Loading Machine occur once during each cycle of the Testing and Date Stamping Machine.

The Testing and Date Stamping Machine consists of two independent electrical test lines on a single machine base. Either test line can be used for testing the 2N559 transistor if all necessary modules are provided. Test Line #1 has been provided with all required modules except for the one testing the Collector-Emitter Voltage, Saturated - V_{CE} (sat) test at I_C = -50mAdc and I_B = -1.5mAdc. The module on Test Line #2 which was built to make this test at I_C = -10mAdc and I_B = -0.4mAdc has been reprogrammed to the higher current bias conditions. Therefore, to provide full test capability on both test lines, two additional V_{CE} (sat) modules would be required - one at each set of bias conditions. In addition, a Forward Current Transfer Ratio Common Emitter - h_{fe} module would be required to complete Test Line #2, since only one has been provided initially. Duplicate modules for performing all other tests have been provided - one on each test line.

Following loading of a card-mounted transistor into a test holder, the holder is indexed to a position under the first test station. A cam mounted on an auxiliary cam shaft raises the test holder into the test position where the three transistor leads contact three fixed test probes. Under control of a cam timer, biases are then applied to the transistor. The length of time biases are applied is controlled by a timer in each test module. After biases have been applied for the specified length of time, the test parameter measurement is made and compared to a standard by comparator circuitry within the module.

If the device under test falls within the limits of the specification an "accept" signal is sent to the accept solenoid which is located immediately following the test probe assembly. Upon receipt of this signal, the solenoid raises a set of reject fingers out of the path of the card-mounted transistor as it is being indexed into a position under the second test station. In case the device under test falls outside the limits of the specification, no signal is sent to the solenoid. During index, as a result, the reject fingers remain in the path of the card-mounted transistor and sweep it off the test holder into the reject bin located directly below. During the free fall of the rejected device it is guided by a metal baffle attached to the moving test holder assembly. Figure 3.18-2 shows the reject fingers in the act of sweeping a card from a test holder during index. The fingers are passing through slots cut in the "Teflon" test holder. The metal guide baffle referred to above is shown just to the left of the test holder assembly.

All rejected units are counted on counters located on the fronts of all test modules. Prior to making each test a continuity check is made to determine if contact has been made to all three transistor leads. In the event the continuity check indicates incomplete or no contact, the device is rejected but not counted. A comparison between the number of rejects counted and the number of devices in the reject bin will determine whether or not there have been any continuity rejects. If the difference is large, corrective action should be taken to eliminate these rejects.

The test and index cycle is repeated as the device moves along the test line. If the device meets all test specifications, it remains on its respective test holder until it reaches the Date Stamping station. At this station the test holder is raised into stamping position by cam action. The transistor can is guided into correct position by a V-shaped "Teflon" block as the test holder is raised. This block compensates for small deviations in can location and provides a clamping action during stamping. The date stamp runs around the periphery of a drum and contains three rings of numbers, each ranging from 0 to 9.

When the transistor has been indexed into the stamping station, the inking pad is rotated through a 90-degree arc by action of a rotary solenoid and contacts the date stamp. The pad is returned to its initial position by spring action. The stamp is then moved forward by an air cylinder until it contacts the top of the transistor can. In order to avoid excessive inking of the date stamp a sensing limit switch is provided to determine the presence of a card-mounted transistor in stamping position.

Following stamping, the devices remain on their respective test holders until swept off by unload fingers. These fingers are exact duplicates of the reject fingers at each test station except they are in a fixed position in order to sweep off all devices. Just before reaching the unload fingers, the good units are counted by a proximity counter set to sense the presence of the metal can. As before, during the free fall of the card-mounted device it is guided by the metal baffle attached to each test holder.

The good unit bins have a capacity of approximately fifteen hundred card-mounted transistors. When the proximity counter reaches this number, the machine is automatically stopped and a yellow light, located on the control panel of the Testing and Date Stamping Machine, is turned on. The machine will not re-start until the counter is re-set.

The index table for the Testing and Date Stamping Machine is a Ferguson Type "A" Trans-O-Mator and is manufactured by the Ferguson Machine Corporation of Indiana. This particular table has 36 carriers, an 8-inch stroke per index, and a fixed ratio of dwell to index of 5 to 1. It is driven by a 1-1/2 horsepower, 220-volt, 60-cycle induction motor through an adjustable speed pulley. The table itself is driven directly by the Ferguson cam drive. It is a rugged table but also has the accuracy and repeatability of index required for this application.

The test module used for making all pulse response tests is manufactured by E-H Research Laboratories, Inc., Oakland, California. This particular unit is E-H Model No. 140, Transistor Rise, Storage and Fall Time Meter. It has been modified by Western Electric Company in order to place critical circuitry as close as possible to the device under test.

Controls for operating this machine are located primarily on the Card Loading Machine which is attached to it both physically and electrically. The Testing and Date Stamping Machine has certain secondary controls located in the center panel of the test module section. In general, they consist of an emergency stop, an end-of-cycle stop, a motor start, a run or jog select switch, and several switches to select the condition for certain operations; for example, whether or not the date stamping mechanism will be operating.

Each test module has a power switch, a counter, an accept light indicating the device under test meets the particular specification, limit checking switches, and external jacks for checking bias currents and voltages.

The duties of the operator of this machine are listed below except for those additional duties required for operating the Card Loading Machine which are outlined in Section 3.17:

1. Check all test module limits at prescribed intervals.
2. Run pulse response test standards through test set at prescribed intervals and record test readings.
3. Monitor all test modules during machine operation to verify that a go no-go decision is being made at each test station.
4. Compare number of devices in each reject bin with number on counter to verify proper operation of all test components.
5. Remove rejects and good product from the machine and keep all required records.
6. Check performance of date stamping mechanism for location and quality of stamping.

All moving parts of this machine have been protected with suitable covers and guards. Critical parts, both mechanical and electrical, have been made fail-safe so that the machine can reject good product but cannot accept bad product in the event of component failure. All mechanisms and test circuitry have been kept simple and have been located in accessible areas to reduce maintenance and downtime.

The physical size of this machine is such that it requires floor space 10 feet wide by 3 feet 1-1/2 inches deep. When Card Loading Machines are attached on both sides this space increases to 12 feet 6 inches wide by 6 feet 3-1/2 inches deep. Adding operator working space requires that an area 15 feet 6 inches wide by 9 feet 2 inches deep be allocated for the machine. The machine weighs approximately 3,000 pounds.

III Machine Development - Technical Problems

The feasibility of mechanizing all testing of the 2N559 transistor was established on the basis of previous experience gained from designs, procedures and techniques developed for the Device 12 D-C and High Frequency Testing Machine provided under an earlier phase of this contract. In addition, a feasibility study of testing problems associated particularly with the 2N559 transistor was made by Measurements Research Company of Philadelphia, Pennsylvania which determined the project was feasible. A third factor affecting feasibility was the availability of commercial equipment for direct reading of pulse response times.

Because of the high ratio of lead length (3 inches) to lead diameter (0.017 inch) of the external leads of the transistor, it was determined that some sort of holder would be required to support the transistor during test. This holder would have to possess the advantage of keeping the transistor leads straight and would have to provide a means of maintaining orientation of the device. Various holder designs were considered and tested.

As mentioned earlier in this report, the transistor is fed into the Testing and Date Stamping Machine mounted on a card material. Development of the proper card, of the test probe design, and evaluation of the direct reading pulse response time test module were carried out simultaneously for a time. Devices were mounted on various card materials and placed in a fixture which caused the test probes to make and break contact with the transistor leads over thousands of cycles. Following initial evaluation of the ability to make good electrical contact, the probes were connected to the pulse response time test set and actual readings were taken. On the basis of this development, the following determinations were made:

1. Any good grade card material could be used for the mounting card since voltages used in testing are small and extremely high dielectric characteristics are not required.
2. Flat, spring type test probes, sufficiently wide to overcome variations in transistor lead location, did not significantly affect test results, and they could be designed to hold up over millions of cycles. The selected probe design is shown in Figure 3.18-3. These probes are 3/16 inch wide at the contact points.
3. Pulse response time tests could be made quickly and accurately with commercial direct reading test equipment using the mounting card and probe design mentioned earlier. It was verified also that certain critical circuitry must be mounted as close as possible to the device under test.

In order to plan for the eventuality of changes in device design or in tests to be performed, all components were made as flexible as possible. This was particularly true of the test modules. While changes in the test to be performed cannot be accommodated, bias and limit condition changes can be made quite easily. Each test module has its own power supplies, timers, and comparator circuitry which makes it independent of all other modules. Since the test set has been in operation, test limits have been altered with no significant loss of production. The external lead length of the transistor has been reduced to 1-1/2 inches and changes to test holders and test probes have been made at small cost.

No unusual design problems were experienced in connection with this machine. Major effort was expended in improving previous similar designs and in providing a reliable yet simple mechanism which would require little maintenance. The largest single mechanical design problems were the Card Cut-Off and Feed Mechanism, which has since been obsoleted by the Card Loading Machine, and the Date Stamping Mechanism. Electrical design was straightforward due primarily to a wealth of experience available from previous effort on manual test equipment.

Construction of this machine proceeded on schedule. There were no major delays due to either faulty design or to design discrepancies. Purchased materials were delivered on schedule and in almost all cases according to specification. Toolroom and test set construction workmanship was of very high calibre.

Following a period of joining together all mechanical and electrical components, prove-in of this machine was started. After the usual tasks of aligning parts and making final adjustments, all mechanical parts were operated at low speed. Basically everything functioned as anticipated, however, two major problems were experienced. First, shot pins provided to assure repeatability of index would bind in the positioning holes and would not release, thereby stopping the machine. Limit switches had been provided to sense the return of the shot pins to normal position for index. Second, jams in the Card Cut-Off and Feed mechanisms would result in damaged devices and in stopping the machine. Both these problems will be discussed in detail in the next portion of this report. Electrical prove-in was accomplished with no major delays.

Prove-in of the Date Stamping Mechanism was accomplished with a limited number of devices. At that time the only devices available with non-tubulated cans were a few experimental units. Basically, the mechanism was operated to see that it performed all required operations in proper sequence. Since the applicable specification for the 2N559 called for the acceptance date on the periphery of the can, it was decided to forego shop trial of this mechanism until date stamping on the top of the can became a reality.

IV Operational Problems

This machine was originally provided with two card cut-off and feed mechanisms, one at each end. Their purpose was to feed a black fibre belt on which the transistors were mounted by a separate semi-automatic card loading mechanism, cut the belt into individual cards each containing one transistor, and feed the resulting cards into the test holders. Several major problems were solved during prove-in of these mechanisms. Guides for the belts and the individual cards were tapered for smoother feeding. A photo-sensing circuit was added to determine that the belt had indexed the prescribed distance before cutting. Vlier plungers were added to prevent the card material from adhering to the cutter blade after cutting. Additional mounts were provided to maintain alignment between the subject mechanisms and the test holders.

Approximately sixty thousand devices were processed through the card cut-off and feed mechanisms during prove-in and shop trial. By the end of this phase they were operating very reliably. However, they have since been replaced by the Card Loading Machine which performs all operations from card loading to feeding inclusive. A study of these operations showed that it was more efficient to take this approach. The machine at present has one Card Loading Machine installed and in operation. A second will be provided as part of Phase 2 of the PEM contract, if its use can be justified.

When the machine was in the design phase, shot pins were added to insure repeatability of index in case the commercial table did not meet specification. During prove-in, however, a great deal of difficulty was experienced due to the shot pins binding in the locating holes. Limit switches were mounted to sense the return of the pins to normal position. As a result, whenever a pin did not return the switch was not activated and the machine was stopped. While the desired protection was provided, the machine did not operate continuously enough to warrant acceptance of this condition.

In order to alleviate this problem, shot pins were re-aligned to insure proper location. Test holder ways which allowed the holders to move laterally as the shot pins entered the locating holes were lubricated. The shot pins were re-ground to provide additional taper for entering the holes. None of these measures seemed to solve the problem. Rather than spend additional time and money attempting to eliminate the problem, it was decided to determine whether the shot pins were really necessary. The machine was operated without them for a considerable period. It turned out that repeatability of index of the table was good enough to permit loading and testing of the card-mounted transistor without their use. Wide test probes and the spreading of the transistor leads for testing were the saving factors in this case. While the shot pin assemblies remain on the machine, they are no longer used.

As mentioned earlier, approximately sixty thousand 2N559 transistors were tested on this machine during the shop trial period. Border-line devices were selected to verify the decision making capabilities of the various test modules. Test modules were monitored using a Brush Instruments recorder to verify bias conditions and test results. It was found that devices under test were being accepted or rejected on an extremely reliable basis within the prescribed accuracy limits of the test equipment.

V Pilot Run Performance

Pilot Run 2N559 transistors were processed over this machine on a continuous basis for a period of approximately three months. During this period approximately one hundred and twenty thousand were loaded and tested. The experiences of the Pilot Run verify the experience gained during shop trial. The mechanical performance of the machine was excellent with no maintenance required. Electrical performance was very good. Some maintenance was required on certain of the test modules due primarily to tube failures.

This run has verified that a properly card-loaded 2N559 transistor can be successfully and reliably tested on this machine. Both reject and good devices selected on a random basis at random intervals of time have been tested on manual equipment to verify the performance of the machine. Devices which are not properly card loaded will be rejected at one of the first two stations depending on which transistor lead is out of place. Rejection occurs because of failure to pass the continuity check. These devices can be re-loaded and re-tested.

Unfortunately there was no opportunity to operate the Date Stamping mechanism during the Pilot Run. This mechanism was designed to place the acceptance date on the top of the transistor can. The applicable device specification, however, still requires this date on the periphery of the can. It is, therefore, put on the can at the same time that all other coding is applied with no lost effort or time.

During the first two months of the Pilot Run the machine was operated at a speed of one index every 4-8/10 seconds. This was done to permit a thorough evaluation of the Card Loading machine before increasing its speed. During the third month it was operated at a speed of one index every four seconds. The theoretical output of the machine at this rate is 810 devices tested per hour. Considering time lost while providing material for the Card Loading Machine and while checking and recording test results (number of rejects at each test and number of good devices) the net output reduces to approximately 750 per hour. Following minor changes to the Card Loading Machine, the machine cycle will be reduced to one index every three seconds.

It should be explained at this point that the Card Loading Machine loads transistors in only 27 out of every 30 holders which pass the loading station. This results from the fact that this machine receives the transistors loaded in magnetic handling trays. These trays are designed in such a manner that 3 out of every 30 test positions cannot be used. This reduces the theoretical output of the Testing and Date Stamping Machine from 900 to 810 per hour with a 4 second index cycle.

During the Pilot Run the Testing and Date Stamping Machine was used for performing the final production electrical evaluation of the completed transistors. Good devices, after this operation, were shipped to Final Inspection where environmental evaluation was made on a sample basis. Units were also subjected to thermal and power aging to check the reliability characteristics of the device. If the sample devices passed all inspection criteria the lot from which they were selected was shipped as good product.

VI Evaluation

The Testing and Date Stamping Machine has been thoroughly evaluated. Its reliability has been proven in continuous operation over several months and approximately one hundred and eighty thousand devices tested. It is capable of performing programmed tests repeatedly with a very high degree of reliability. It is accurate within the limits of the test module components. Device acceptance criteria are set at values which compensate for any narrow deviations in test modules to eliminate any possible chance of accepting bad product. No special skills are required to operate this machine.

The major advantages of this machine's performance over completely manual testing are speed and reliability. The first mentioned advantage is obvious when observing both methods of testing. The second advantage can only be realized by evaluating both good and bad devices resulting from using both methods of testing. In all cases where different results were obtained during prove-in when comparing manually and machine tested devices, the results obtained by the machine were the correct ones.

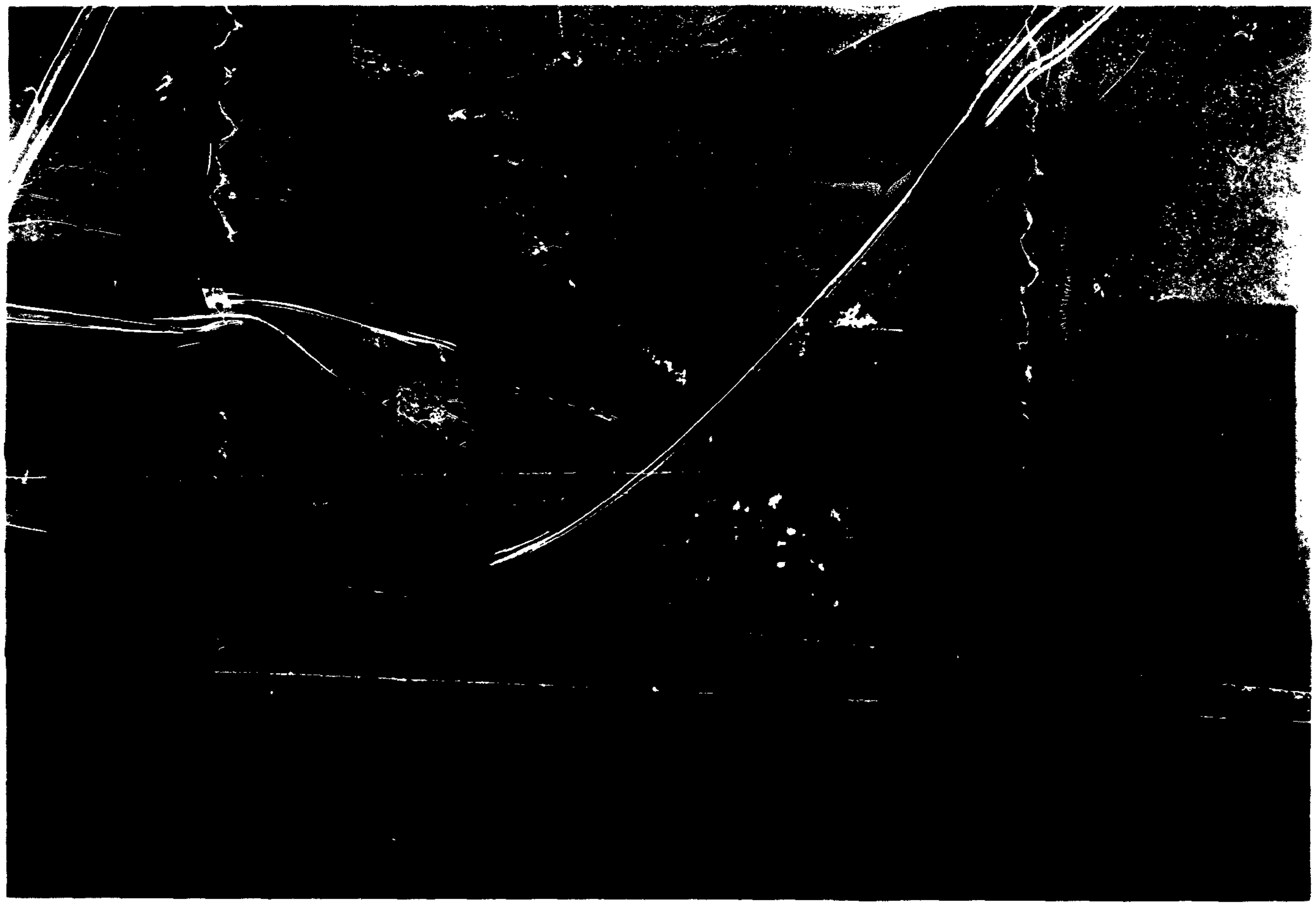
VII Conclusion

The success of this machine can best be measured by its performance. It is being used on a daily basis performing all its required functions with the exception of date stamping which is presently not required. All the original goals set for this machine have been met.

As a result of building this machine advances have been made in techniques for supporting long-leaded transistors during testing, in testing rapidly and reliably on a go no-go basis, and in performing pulse response tests on a mechanized basis.

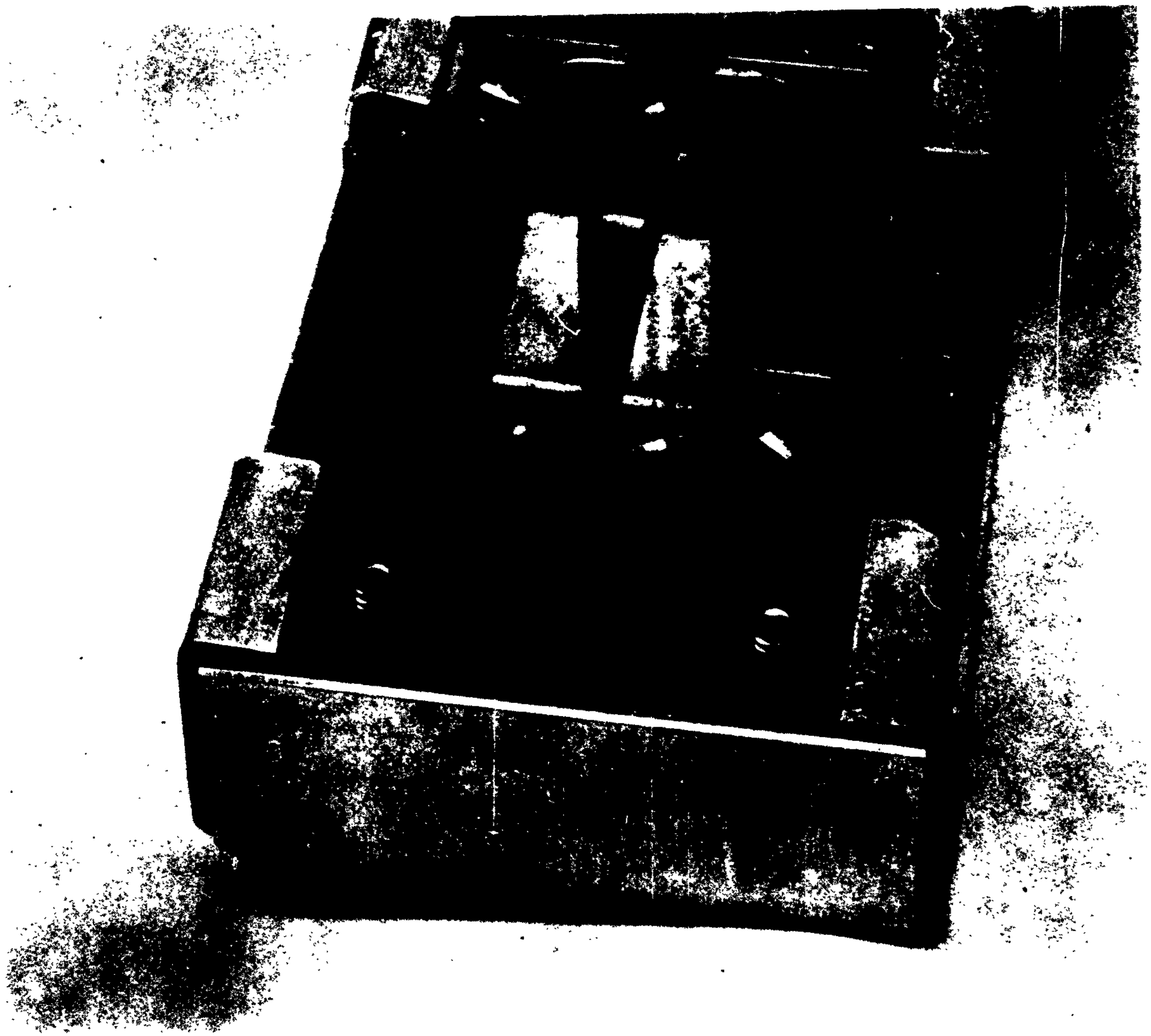
Three minor improvements can be suggested for this machine. It would be advantageous to provide an initial test station which would reject all open or shorted devices plus improperly loaded units. This would have the effect of separating that type of failure from genuine first test rejects. It would be helpful to have visual bias condition checks through use of meters mounted on the face of the test modules. Responsibility for these checks could then be given to the operator provided some means of showing correct settings were available. Complete lubrication of the Testing and Date Stamping Machine is a time-consuming process due to the need for removing guards and covers. This task could be considerably eased by providing a continuous lubrication system which could be manually controlled from a single point.

It is intended to thoroughly evaluate this machine during the forthcoming Phase 2 period. Any improvements which are feasible and practical in the light of the production requirements specified in the PEM Contract will be made.



TESTING AND DATE STAMPING MACHINE WITH
CARD LOADING MACHINE ATTACHED
FIGURE 3.18-1

REJECT FINGERS OF TESTING AND DATE STAMPING MACHINE
REMOVING CARD LOADED TRANSISTOR FROM TEST HOLDER
FIGURE 3.18-2



TEST PROBES OF TESTING AND DATE STAMPING MACHINE
FIGURE 3.18-3

SECTION 3.19

DATA HANDLING

D. H. Lockart

DATA HANDLING

I General

The Data Handling System consists of semiconductor device test equipment, analog to digital conversion equipment, data recording devices, and a computer. The system is used to generate electrical test data, to process the resultant data, and to convert it into forms useful for engineering evaluation.

The most critical requirement placed upon this system is that of reliability. It is extremely important that accurate bias conditions and test readings be established by all test equipment. No major alterations in data are permitted during conversion to digital form or during the recording operations. The computer must be able to receive and process all data with a high degree of accuracy. In most cases samples of production lots are tested and analyzed on this system. Decisions arrived at on the basis of sample performance often affect large numbers of completed semiconductor devices.

In selecting the various components of this system, consideration was given to reliability, versatility, availability, cost and speed of operation, essentially in that order. Every attempt was made to utilize commercially available equipment which met these criteria. Results obtained indicate this goal has been fulfilled.

Prior to provision of this system only limited data recording and processing equipment was available. D-C measurements only could be automatically recorded on the medium of punched cards. Any tests other than D-C had to be performed manually, recorded manually and subsequently manually punched on the data cards. The only equipment available for processing the resultant cards was an IBM 101 Electronic Statistical Machine. This limited data analysis to that which could be done using card sorting techniques.

The major shortcoming of this equipment was the fact that it was limited essentially to D-C measurements. In the event additional data of a non-DC nature was needed, it could be procured only on a manual basis with the resultant loss of reliability. The available equipment was designed and built primarily for the 2N559 transistor which meant that its versatility was limited.

Early in the development of this system it was determined that highly reliable data handling equipment was needed on an "on-line" basis to provide rapid feedback of information. As semiconductor assembly operations were speeded up through the use of mechanized equipment, results of quality control and production control evaluations were needed within hours rather than days. In anticipation of Nike Zeus production some method of procuring, recording, and processing information accurately and quickly was needed.

Rather than build a system of extremely high cost, it was decided that up-to-date testing capability would be procured, but that a relatively inexpensive computer would be used. This would permit evaluation of data processing on an "on-line" basis without the high cost of a large computer. Possibly some sacrifice in reliability might have to be made and certainly considerable sacrifice in speed since computer cost is approximately proportional to processing speed. The major shortcoming of the present system is the speed of the computing portion, particularly as it is limited by the speed of input of the data to be processed. However, this has not been a deterrant to the use of the system for development purposes.

The system has fulfilled all requirements placed upon it and has been used for inspection and control of the 2N559-2N1094 and 2N560-2N1051-2N1195 mechanized production runs. All components of the system have been used successfully. While it is not a high-speed system it is highly reliable and extremely useful.

II Description of System

The Data Handling System consists of a complex of inter-related items of commercially available equipment. There are eight items of equipment in the system. These items with the manufacturer's identification are given below:

Item #	Name	Model #	Manufacturer
1	Transistor & Component Tester	520	Texas Instrument, Inc.
2	Printing Summary Punch	526	International Business Machines Corp.
3	Auxiliary Paper Tape Punch	ATP	Friden, Inc.
4	Flexowriter	SPS	Friden, Inc.
5	Automatic Switching Time Test Set	420-1	Lumatron Electronics, Inc.
6	Digital Voltmeter	581	Delaware Products Co.
7	Card Punch	028	IBM
8	Computer	Mark XI	Monroe Calculating Co., Inc.

The relationships of the various items of equipment to each other and to the system as a whole are shown in Figure 3.19-1.

Test capability is provided by the Transistor and Component Tester (TACT) and by the Automatic Switching Time Test Set. The former performs D-C and 1 kc "h" parameter measurements and the latter pulse response tests.

TACT is a versatile piece of test equipment capable of making up to 20 electrical tests on either diodes or transistors. These tests may be selected from a pre-determined set of 29 D-C and/or 1 kc "h" parameter test configurations. Tests are made sequentially on each semiconductor device inserted into the test socket.

Test conditions are programmed by means of punched cards inserted into a Hickok Electrical Instrument Company Cardmatic Card Reader. Punching or non-punching of the various hole positions selects the test to be performed, the bias conditions, the length of time the bias conditions are to be applied before the test result is read, maximum and/or minimum test limits, and the full scale value of the readout digital voltmeter.

After tests have been selected and the various program cards inserted into the card readers, a device is inserted into the test socket. TACT will then sequentially make all programmed tests on the device. The device can be of P-N-P or N-P-N configuration. A visual readout of the test results is given by a digital voltmeter which is an integral part of the TACT system. If desired, test results can be recorded on punched cards using the IBM 526 Printing Summary Punch or on punched tape using the Friden Auxiliary Paper Tape Punch. Results can also be recorded as typewritten data by connecting the Friden Flexowriter to TACT and feeding the output tape from the Auxiliary Punch directly into the Flexowriter tape reader. A duplicate tape can be generated at the same time, if desired. TACT is shown in Figure 3.19-2 with the punched card recording capability attached. The punched paper tape components are shown in Figure 3.19-3.

Pulse response tests can be performed on either 2N559 or 2N560 type devices. These plus the 2N1072 are the only PEM Contract codes which have switching time parameters in their applicable military specification at present. 2N1072 pulse response capability was not provided because of a lack of a production program for this device. In the event that additional capability is needed, test boards to make the required tests can be provided at short notice and with little cost. These test boards are a part of the test socket circuitry. The Lumatron Automatic Switching Time Test Set will perform any or all of the following six tests:

Pulse Response - Delay Time - t_d

Pulse Response - Rise Time - t_r

Pulse Response - Turn-on Time - t_{on}

Pulse Response - Storage Time - t_s

Pulse Response - Fall Time - t_f

Pulse Response - Turn-off Time - t_{off}

Programming of the various tests plus digital readout of the test results is accomplished by the Delaware Products Digital Voltmeter. This component is directly connected to the switching time test set and also connects directly with the Friden Flexowriter. Either automatic sequencing from test to test with automatic readout or automatic sequencing with operator control of readout may be selected.

Devices to be tested are manually inserted into the test socket. Testing is started by the operator by automatically printing the unit number of the device. From that point on for the device in the test socket,tests are made and results recorded without further operator control. Output data can be recorded by the Flexowriter on a punched paper tape, on a typewritten sheet, or on both simultaneously. The Lumatron Automatic Switching Time Test Set, the Delaware Products Digital Voltmeter and the Friden Flexowriter are shown on Figure 3.19-4.

The computer used in the Data Handling System is a Monrobot Mark XI desk-size, solid state computer. Data read-in devices used in connection with the computer are an IBM 024 Card Punch for punched card input, two Monroe Calculating Company punched tape readers, and a typewriter directly connected to the computer. Output devices are a Monroe punched tape punch and the previously mentioned typewriter. The Friden Flexowriter is used to prepare and edit program tapes for the Monrobot. The computer and its associated equipment are shown in Figure 3.19-5.

All the IBM equipment and the Monrobot are retained on a rental basis so that maintenance of these items is the responsibility of the renting companies. Maintenance contracts for TACT and for the Friden Flexowriter were negotiated for the period of system development to permit training of local maintenance personnel. Servicing of all other system components is handled by Western Electric Company.

Operator's duties in connection with all items in the system entail manual insertion of devices into test equipment and the manual insertion on a lot basis (roll of tape or deck of cards) of data into read-in, recording, or computing equipment. From this point on the operator must monitor all operations to determine that the system's functions are being reliably fulfilled.

III Machine Development

Two feasibility studies of the Data Handling System were made - one by Texas Instruments Incorporated and the other by Daystrom Instrument, Division of Daystrom Incorporated. The Texas Instruments' study proposed two alternate systems. The first system proposed was a prototype automatic life test and measuring facility to be designed and built to Western Electric Company specification. It consisted of test equipment for making all Group A, B and C tests found in the 2N559 type transistor military specification, mechanical handling equipment for handling the transistors mounted on the card used in previous production line testing, analog to digital conversion equipment for test results, and a tape punch, tape reader, flexowriter system for recording and printing out resultant data. The second system suggested was to use three Texas Instruments Sequential Mechanisms for Automatic Recording and Testing (SMART), three Switching Time Auxiliary Consoles, IBM punches, readers and typewriter features for data recording, and a Distribution Readout attachment for plotting parameter distributions. Three SMART units were required to provide the hourly testing rate of 500 devices/hour specified at the time of the feasibility study.

The Daystrom Instrument study proposed a Life Testing and Recording Facility to be designed and built to Western Electric Company specification. It would consist of test equipment with programmable power supplies, analog to digital conversion equipment, card punches, card reading and printing consoles, and card sorting equipment. The test program would be punched on a continuous loop of tape which would be fed into a tape reader in the test console.

Both feasibility studies outlined methods for handling transistors during testing, for performing the various tests required, for converting analog signals to digital readout, and for recording and processing the resultant test data. These studies were very useful in subsequent development of the system and together formed the basis for the system as it exists today. In addition, consultations were held during this stage of development with members of the staff of the Western Electric Engineering Research Center, Princeton, New Jersey with regard to the data processing aspects of the system.

Quotations received with the feasibility studies showed that the costs of providing a complete system as outlined in the specification would be very expensive. As a result the specification was reviewed in an attempt to provide the most system with the least expense. It became apparent that the best method of accomplishing this was to make as full usage as possible of available commercial equipment. The need for sophisticated transistor handling equipment was also investigated, and it was decided that this was not necessary in inspection type testing equipment. A third method of reducing initial costs which was selected was to rent rather than purchase data handling equipment. A decision was made after study of the feasibility reports to reduce the scope of the system from complete 2N559 testing to testing all milliwatt devices on four D-C parameters. The parameters proposed were I_{CBO}, I_{EBO}, V_{CE} (sat) and h_{FE}. It was decided that the test modules and the appropriate control circuitry would be designed and built by the Western Electric Company. Analog to digital conversion equipment and data processing and recording equipment would be purchases or rented. Design of the modules and the control circuitry was completed and the required digital voltmeter was ordered on a custom basis from Delaware Products Company, Laurel Springs, New Jersey.

Early in 1961 a data handling committee was formed at Laureldale to review plant-wide needs in this area. PEM Contract requirements in data handling were made known to this committee so that they could be considered with other plant requirements. This committee reviewed various commercially available items of test equipment and highly recommended that a Texas Instruments TACT be purchased to provide D-C and 1 kc "h" parameter test capability for the Data Handling System. The availability of this equipment had been publicly announced only a short time before the data handling committee was formed. Its versatility made it extremely useful since the PEM Contract under which this system was being provided had been modified to include additional codes.

Within a short time following the decision to purchase a TACT the system concept was established and all components ordered. Design was essentially complete since all parts were available "off-the-shelf" with the exception of the digital voltmeter ordered from Delaware Products Company. Production of this item was halted until its place in the system could be determined.

No switching time capability was available with TACT at the time of its purchase. Various available switching time modules were evaluated, and a decision was made to use a Lumatron Electronics Automatic Switching Time Test Set. The Delaware Products Company Digital Voltmeter was subsequently modified to include control and test sequencing circuitry in addition to its analog to digital conversion equipment so that it could be used in conjunction with the Lumatron Test Set.

Recommendations on recording and computing equipment came primarily from the Western Electric Engineering Research Center. The Center had previously evaluated the Monrobot Mark XI Computer and felt that its capabilities were definitely in line with Laureldale's production data handling needs at the time. The original plan was to use punched tape as the data recording means. However, it was decided in the interim to also provide punched card capability in order to integrate the system with existing card processing equipment.

Construction of all components was carried out by the various suppliers in their own plant locations. Only in the case of TACT, Western Electric engineers visited the manufacturing facility for preliminary check-out and acceptance before shipping.

The computer was received several months in advance of the test equipment ordered for the system. This provided an opportunity to develop and prepare computer programs while awaiting the arrival of the test equipment. The following programs have been developed for the computer and used in production data handling:

1. Histogram Program

This program results in test value distributions showing the number of devices which fall in each cell. Shop limits, specification limits, and the 10, 50, and 90 percent points on the distribution can be shown, if desired.

2. Step-Stress Evaluation Program

This program gives a comparison between test data taken before and after step-stress evaluation. Since units are identified the program can give the net change in parameter value or the percent change whichever is desired. Devices which change more than a specified amount of percent can be identified.

3. Code Sorting Program

This program permits evaluation of semiconductor test data to determine the number of devices meeting various code specifications. This is useful in determining yields to be expected in modifying existing codes to meet new specifications. It was written specifically to allow evaluation of test data on particular devices in the light of several specifications.

4. Funnel Lot Analysis

This program analyzes samples of semiconductor wafer lots and determines yield by parameter, overall yield, and parameter data distributions. It then ranks the lot and determines whether of not the lot should be released for production.

5. Failure Mode Analysis

This program analyzes semiconductor test data and determines the number of devices failing to meet the applicable specification. It also specifically determines the parameters which have been failed and gives the number of devices failing each parameter limit.

During the period preceding the arrival of the Transistor and Component Tester (TACT) development, design and construction of a transistor handling mechanism was undertaken. The purpose of this development was to provide a means for sequentially indexing semiconductor devices into the test position provided for TACT. A 10-unit rack was designed for holding devices to be tested. This rack consisted of an assembly of 10 custom designed Loranger Manufacturing Company sockets. Following loading of 10 transistors into the sockets,the rack was to be placed in an index carriage. This carriage was to be indexed one position at a time thereby allowing each socket in turn to contact a fixed set of test probes. The index carriage was to be indexed by means of an air cylinder, a rack and pinion, and a suitable gear train. A magnetic clutch was added to permit manual return of the carriage to the initial position for insertion of a new rack. Index and test starts were activated by TACT.

The sockets used were selected originally for use on power aging racks which were in the design stage at the same time. As it turned out the socket design was not reliable enough for this application. As a result, the rack approach was discarded as being too expensive for the single application to TACT testing.

A new approach to handling semiconductor devices during testing on TACT will be considered during the Phase 2 portion of the contract. It is planned that manual loading and unloading of devices will still be required, but control of index and of the test cycle will remain a TACT function.

IV Operational Problems

Prove-in of card punches, card readers, the computer, the auxiliary tape punch, and the Flexowriter was handled by the various factory representatives. These prove-ins required only a few hours of effort and will not be discussed here. Primary effort during prove-in of the system was concentrated on TACT and the mating of the Lumatron Automatic Switching Time Test Set with the Delaware Products Digital Voltmeter.

Prove-in of TACT components was handled by a Texas Instruments' service engineer. Western Electric prove-in consisted mainly of tailoring the test facility to the unique characteristics of the devices to be tested and the tests to be made. Since TACT is considered a universal test set it is designed to be able to test a broad range of devices. Unfortunately, however, certain tests on certain devices cause the device to oscillate, thereby producing false readings. As a result it was necessary to make additions of capacitors and resistors to the test circuitry in order to eliminate these oscillations. Samples of all contract devices were tested on all tests which could be programmed on TACT to determine that oscillations were eliminated. This problem was not completely eliminated, but it has been reduced to the point where it can be dealt with effectively.

Prove-in of the Lumatron Test Set and the Delaware Products Digital Voltmeter was complicated by voltage transients which triggered the Lumatron at incorrect portions of the test cycle. This would have the effect of causing the Lumatron to react as if a test reading had been converted and recorded and it was time to make the next programmed test. On other occasions these transients would cause the Lumatron to produce a negative reading on the turn-off time measurements. This, of course, would mean that incorrect information would be recorded.

The problem of transients was eliminated by the addition of relays to isolate the two pieces of equipment from each other during date recording and test sequencing. This means that the two components will be directly connected only long enough for the Lumatron to get a "start-test" pulse from the control module and for the digital voltmeter to get the output analog voltage from the Lumatron.

Shop trial of the Data Handling System was carried out over a period of one month. The following devices were tested on TACT:

Transistor Type	Quantity Tested
2N559	17,279
2N1094	1,512
2N560	1,000
2N1195	2,212

Tests performed on these devices consisted of leakage current tests, voltage breakdown tests, saturation voltage measurements, and 1 kc "h" parameter tests. A minimum of eight tests were made on each device. Switching time measurements were made on the Lumatron on approximately eighteen hundred 2N559 transistors. At least three switching tests were made on each device.

Data from these devices was recorded and processed to evaluate all of the data handling components of the system. The computer was used primarily to plot distributions of the various parameter values and to determine yield. All system components functioned properly during the shop trial period. Operators were trained on all components, so that the system could be operated on a production basis without engineering supervision except for computer programming.

V Pilot Run Performance

The Data Handling System was used during the mechanized pilot run for the following purposes:

1. Provide data, yield evaluations, and distributions for "funnel lot" evaluation.
2. Provide data, yield evaluations, and distributions on production samples.
3. Provide data for final inspection purposes, for example, readings and distributions before and after thermal or power aging.
4. Provide test data for correlation samples to be submitted to the U. S. Army Electronics Materiel Agency to meet contract commitments.
5. Provide test data on quantities of devices to be submitted to the U. S. Army Electronics Materiel Agency to meet contract commitments.

Approximately 75,000 devices were processed over the components of the Data Handling System during the period of the pilot run. No major problems were experienced during this period. On occasion maintenance was required on various electronic components, but it was not excessive.

No specific production rate can be established for this system. The elapsed time for testing a single device is dependent upon the number and kinds of tests to be performed, upon whether or not data is to be recorded and upon the data recording medium - cards or tape. For example, test bias application times of 1/4, 1/2, 1, 3, 5 or 10 seconds can be selected.

VI Evaluation

All components of the Data Handling System have been thoroughly evaluated. Their reliability appears to be at a level commensurate with the state of the art of the particular equipment. The system is capable of operating over long periods of time provided preventive maintenance procedures are followed. It is easy to operate which eliminates the necessity for long periods of operator training.

The use of this system has made possible rapid "on-line" evaluation of semiconductor processing at Laureldale. Greater amounts of detailed information presented in more meaningful form have become available much faster than was previously possible. The availability of the system has permitted broader use of "funnel" evaluations to control and monitor production processes. While the present system is limited by computer speed, its value as a development tool has been established.

VII Conclusion

The success of the Data Handling System has been measured by its performance. It is available for evaluation and control of the manufacturing of milliwatt transistors and diodes. As a result of the development of this system, accurate and reliable data can be made available within a practical and meaningful time interval for production and engineering evaluation.

General improvements can be suggested for the system. First and foremost, if the system is to expand its capabilities, a higher-speed computer with larger storage should be procured. The present computer with its slow data input and output capabilities limits rapid feedback of information. In certain instances special engineering studies could not be made due to a deficiency of data storage capacity in the computer.

Transistor handling equipment should be considered for TACT. Testing speed can be increased by permitting the test set to control certain phases of the testing cycle. Reliability can possibly be increased by more positively assuring proper unit sequence. Updating of certain TACT components should also be investigated.

A final decision on the use of punched cards or punched paper tape should be made. If a different computer is considered, this problem will likely be solved at the same time. All components should be made compatible with the system selected.

It is intended that the system will be evaluated during the forthcoming Phase 2 period. Any improvements which are feasible and practical in the light of the production requirements specified in the PEM Contract will be made.

DATA HANDLING SYSTEM

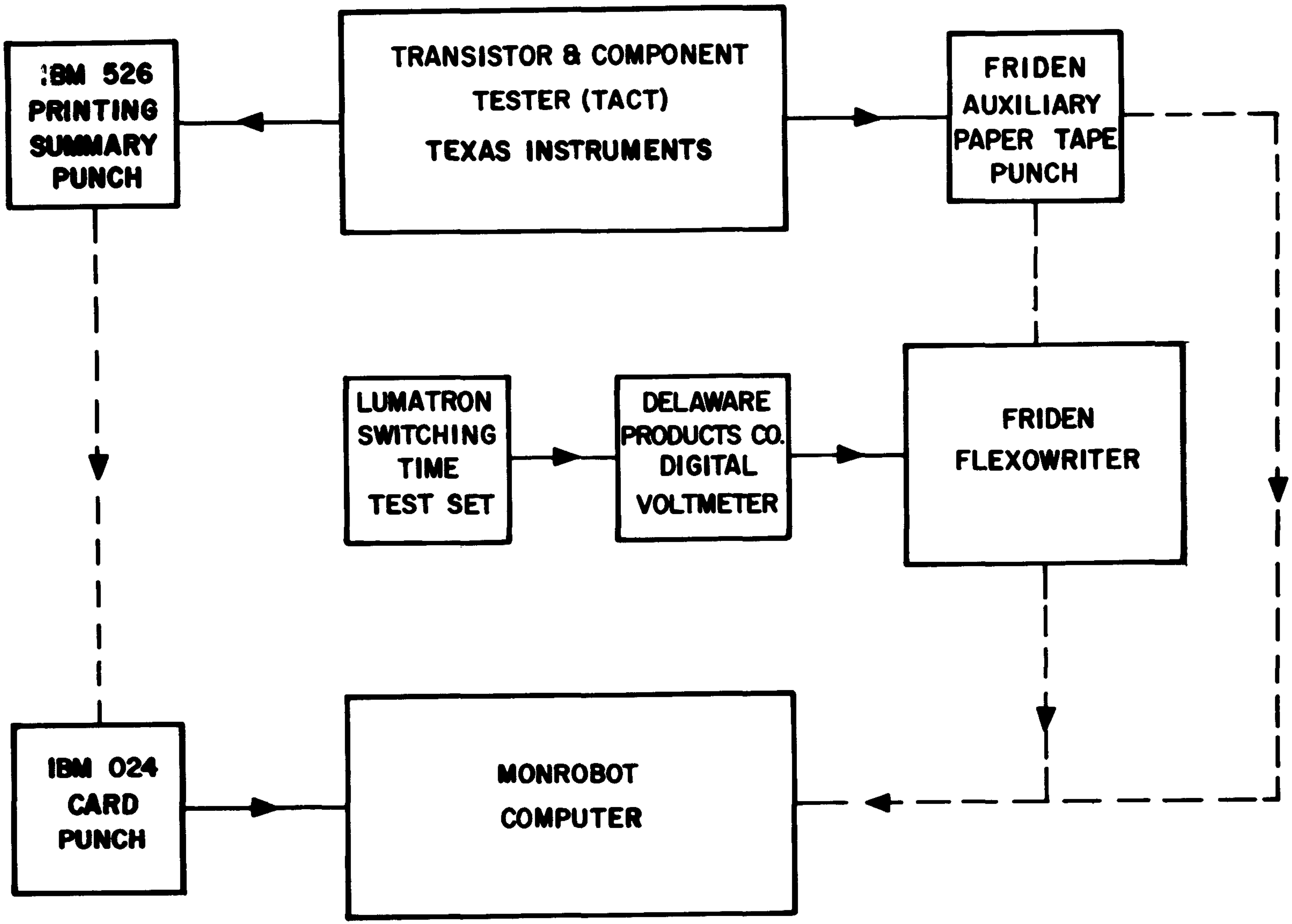
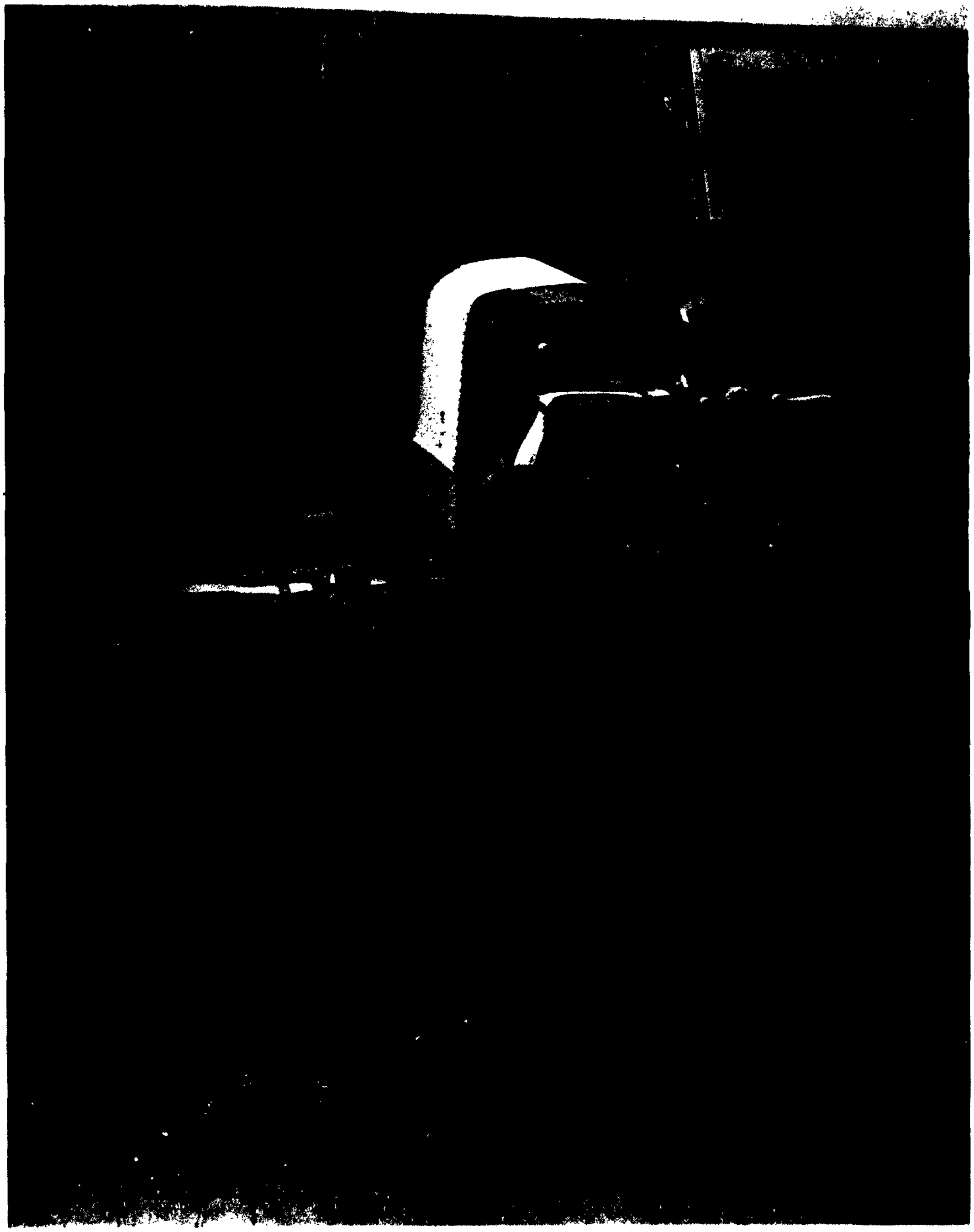
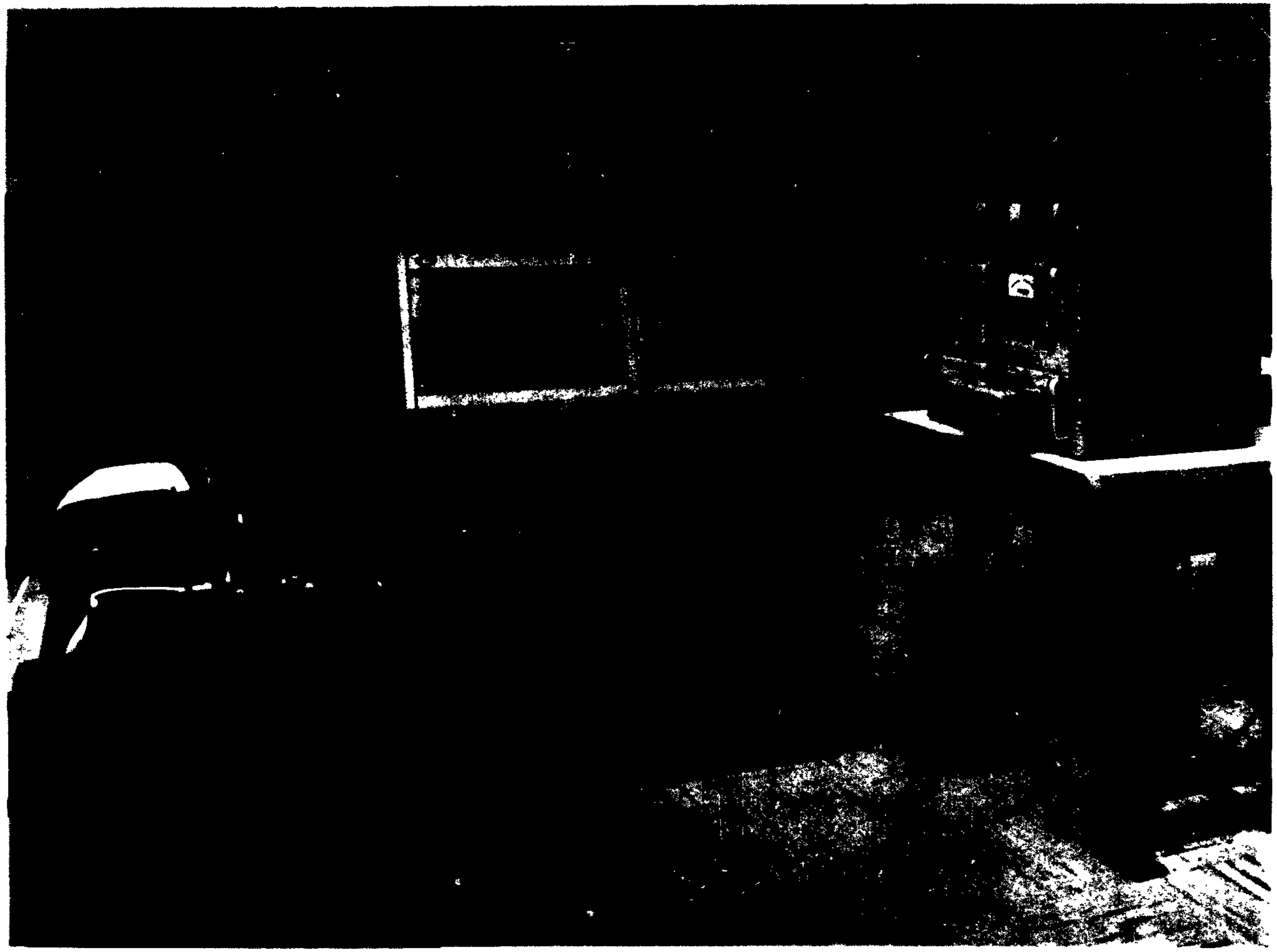


FIGURE 3.19-1

TRANSISTOR AND COMPONENT TESTER (TACT) WITH LBM 526
PRINTING SUMMARY PUNCH ATTACHED
FIGURE 3.19-2



FRIDEN AUXILIARY PAPER TAPE PUNCH AND FLEXOWRITER
FIGURE 3.19-3



LUMATRON AUTOMATIC SWITCHING TIME TEST SET, DELAWARE PRODUCTS
DIGITAL VOLTMETER AND FRIDEN FLEXOWRITER
SET UP FOR SWITCHING TIME TESTS
FIGURE 3.19-4

MONROBAT COMPUTER AND ASSOCIATED EQUIPMENT
FIGURE 3.19-5

PHYSICAL CHARACTERISTICS AND SERVICE REQUIREMENTS OF THE VARIOUS COMPONENTS OF THE DATA HANDLING SYSTEM

Item	Length	Width	Height	Est. Wt.	Services
Transistor and Component Tester	6'0"	2'8"	6'6"	2000#	110V - 60 cycle - Single phase
Printing Summary Punch	2'4"	2'8"	3'3"	500#	" " "
Auxiliary Paper Tape Punch	1'0"	1'0"	2'2"	30#	" " "
Flexowriter	4'8"	2'0"	2'11"	150#	" " "
Automatic Switching Time Test Set	2'6"	2'6"	2'5"	150#	" " "
Digital Voltmeter	4'7"	1'10"	4'0"	300#	" " "
Card Punch	2'4"	2'8"	3'3"	500#	" " "
Computer (3 Sections)	4"0"	2"0"	2'4"	500#)	
	4'3"	2'1"	2'4"	300#)	" " "
	2'3"	2'3"	2'4"	200#)	

Figure 3.19-6

SECTION 3.20

CARD PACKAGING

C. R. Fegley

CARD PACKAGING

I General

The Card Packaging Machine fabricates and assembles the special package required by the 2N559 Transistor Insertion Machine for the Nike Zeus A Package. This special package consists of a punched mylar belt (Figure 3.20-2), card mounted 2N559 transistors which are locked to the belt by punched tabs, and a reel (Figure 3.20-4). As shown in Figure 3.20-2, the card mounted transistor are accurately locked in the shipping belt on 1-1/4-inch centers with the leads spread for electrical testing if desired.

The Card Packaging Machine prepares a shipping belt by punching tabs and notches into a plain tape made of "Mylar", indexes the belt through a loading station, and winds the loaded belt onto a shipping reel. At the loading station, it raises two tabs so that an operator can place card mounted transistors between the tabs. An efficient operator can package approximately 1,700 devices per hour.

During development of the Card Packing Machine, means of fabricating a disposable shipping reel and belt were sought. This goal was attained. A simple Reel Assembly Machine is, therefore, provided to assemble disposable reels as needed.

II Machine Description

The Card Packaging Machine (Figure 3.20-1) was designed to mount on and become part of a 30-inch-wide by 72-inch-long bench. It consists of a belt supply station (1), heated platens (3), a punch press (4), index stations (5), a loading station (6), a take-up station (2) and an electric counter (7). The total weight of the machine is 2,100 pounds.

The inputs to the machine are card mounted 2N559 transistors, shipping reels, and .010-inch-thick by 2-3/8-inch-wide "Mylar" tape wound on 18-inch rolls. After a reel of tape is placed on the machine, it is fed through the heated platen into a "Benchmaster" punch press which forms a locating stop and punches locking tabs, a V-shaped notch, and holes for indexing the tape. The heated platens preceding the punch press make the "Mylar" more pliable so that the locating stop near the back edge of the belt can be formed and provide increased die life.

The punch press is driven by a 1/3-horsepower motor mounted on the press. While manual indexing is necessary for starting a new reel of tape, the press is operated by depressing the large mushroom button to the left of the punch press. Once the initial length of belt is punched and started on the indexing drums, the indexing speed is controlled by a variable speed drive. A cam mounted on the driveshaft times the punch press to the indexing cycle by engaging the clutch of the punch press through a solenoid. A time delay mechanism holds the solenoid closed until the press is actuated; then, a hold circuit and mechanism stops the press after each cycle. The indexing drive motor can be stopped temporarily as necessary by depressing a foot-switch after the "run" button is depressed to start the machine. This gives the operator free use of both hands while loading the belt.

A common drive shaft drives the first indexing drum at the punch press, the second indexing drum at the left end of the machine, and the two fingers (Item 1, Figure 3.20-2) at the loading station. These fingers, one on either side of the loading station, raise the two punched tabs (Item 2, Figure 3.20-2) in the belt when the fingers move down. This permits the operator to place a card mounted transistor on the belt between the tabs as shown in Figure 3.20-2. When the fingers retract, the tabs clamp the card mounted transistor to the belt.

A card counter records the number of times the loading fingers are actuated and, at the end of a given lot, actuates one air cylinder which moves the loading finger cam roller sideways to disengage the loading fingers and another air cylinder shifts the variable speed drive to increase the speed of the machine for punching a tail and a leader. After a predetermined length of tail and leader have been punched, the counter automatically stops the machine, re-engages the loading fingers, decreases the speed for normal loading, and resets the counter.

Through the counter and a selector switch the machine can be programmed to continuously load card mounted transistors for shipping large quantities on reels containing up to 1,000 transistors or it can be programmed to load the belt in any predetermined pattern for cutting the belt into small strips containing small quantities of card mounted transistors. The small strips would be placed in packages for shipping small quantities.

An auxiliary machine (Figure 3.20-3) was built to assemble the reels on which the card loaded belt is wound for shipping. This machine forms and shapes the ends of the thermoplastic core (Figure 3.20-4) over flanges through pressure applied to a heated platen. A heat control regulates the temperature of the molds and a time delay regulates the molding period. Depressing the foot switch, after the core and two flanges have been placed into position, activates the compressed air which closes the heated platens over the core ends. As the plastic is heated, it flows under the combination of heat and pressure to form a lock ring over the two flanges. At the end of the molding period the platens are automatically retracted and the cycle is complete.

This machine was designed to set on top of a standard work bench and occupies an area of 30 inches by 30 inches. It weighs approximately 250 pounds.

III Machine Development

In order to automatically feed transistors into a machine at high speed a special package had to be developed that would accurately position transistors in the Nike Zeus Transistor Insertion Machine. The package originally developed consisted of a metal reel, card mounted 2N559 transistors, and a shipping belt which had plastic pockets riveted to it, into which the card mounted transistors were inserted. This package was expensive and was to be returned by the customer for refilling.

The design of the Card Packaging Machine was started using the above package and having a trimming station for cutting the leads of the transistor. The trimming station was eliminated when the length of the lead was changed from 3 inches to 1-1/2 inches. This simplified the design of the packaging machine and permitted the estimated speed to be increased by 200 percent.

During the design of the Card Packaging Machine an effort was made to make the package less expensive. A belt made of .010-inch-thick "Mylar" with tabs and indexing notches punched in it was substituted for the belt with riveted pockets. Not only was this belt lower in cost but was superior to the original design. The design of the Card Packaging Machine was changed to use the new belt.

Then, the cost of the metal reel was the only item that prevented the package from being low enough in cost to throw away. A price quotation of $160 each in quantities of 12 was received on the metal reel which was designed for the Nike Zeus Transistor Insertion Machine. A single reel using two cardboard flanges and a thermoplastic core having a double 1/8-inch keyway in the bore as required for the insertion machine was developed. In quantities of 1,000 reels its price was reduced to 47 cents each. In addition to its low cost, additional savings are realized in the storage space required and through a decrease in shipping weight. The total cost of the package including the reel and the "Mylar" tape is approximately $2.65 per 1,000 transistors. This price does not include labor. The cost of this package is now low enough that it need not be returned yet the package is sturdy enough to be re-used many times if desired.

IV Machine Performance

The Card Packaging Machine was built directly from the engineers sketches and layouts. As parts for the machine were completed, they were installed and proven-in, leaving few problems for final prove-in. A random double stroke by the punch press and improper functioning of the predetermining counter were the only problems that had to be overcome.

The punch press double stroke was easily eliminated through the addition of an electric interlock in the control circuit of the punch press. This completely eliminated the random double stroke of the punch press.

The predetermining counter failed to reset itself after reaching the maximum preset count. Another problem was the counter resetting itself when the power to the machine was turned"off". By modifying the counter and adding a time delay relay in the control circuit, these problems were eliminated.

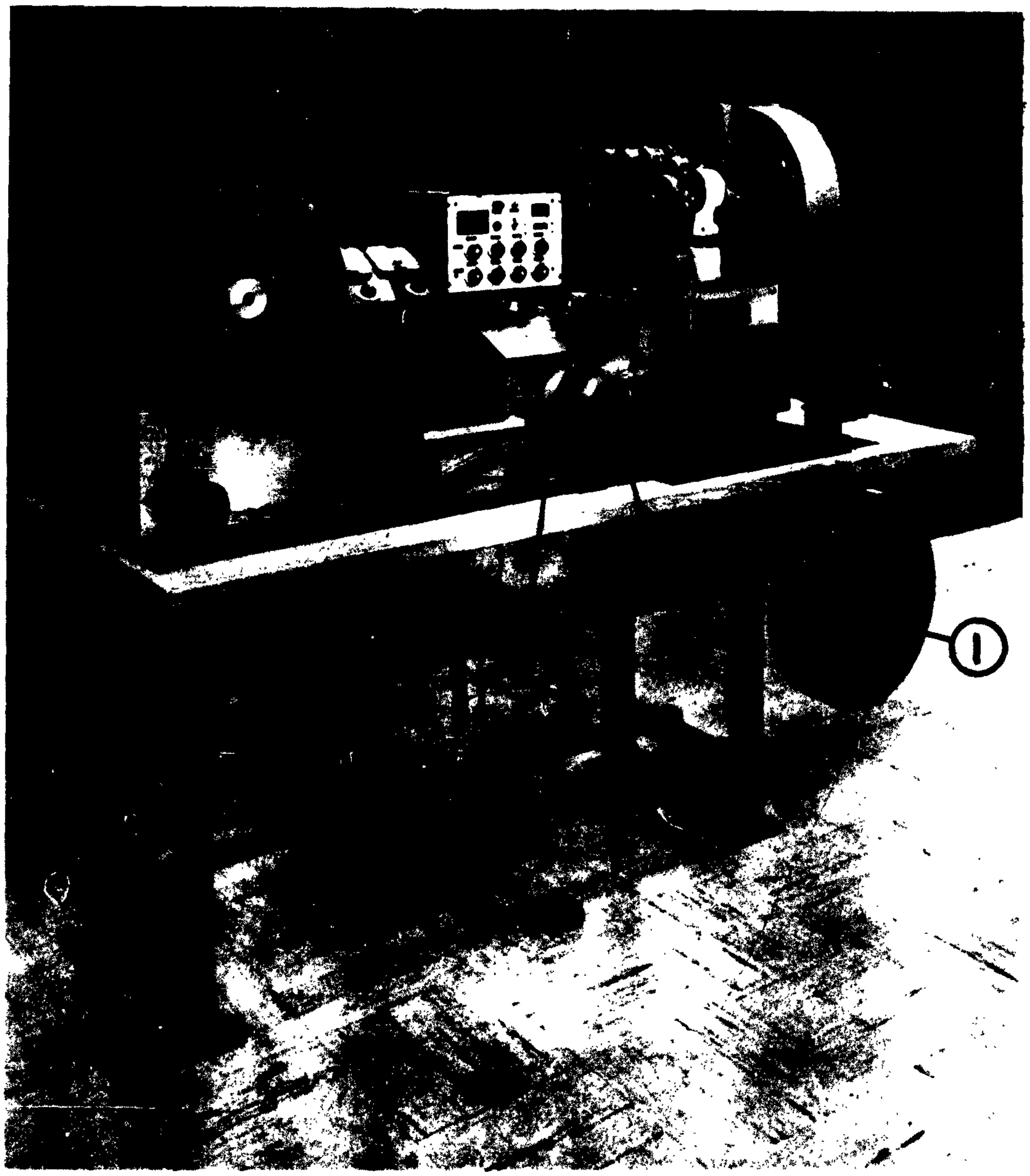
During the shop trial, approximately 8,000 units were loaded on the Card Packaging Machine. As the operator became familiar with the machine, her speed in loading increased to approximately 1,850 units per hour. As more experience is gained, it is expected that an average operator could load the machine in excess of 2,000 units per hour.

The Reel Assembly Fixture was also assembled from sketches. After the temperature, pressure, and forming times were determined, no problems were encountered. The dies for making the thermoplastic core for the reel were made and proven-in by the General Mold Company. No problems were encountered with the dies or the cores.

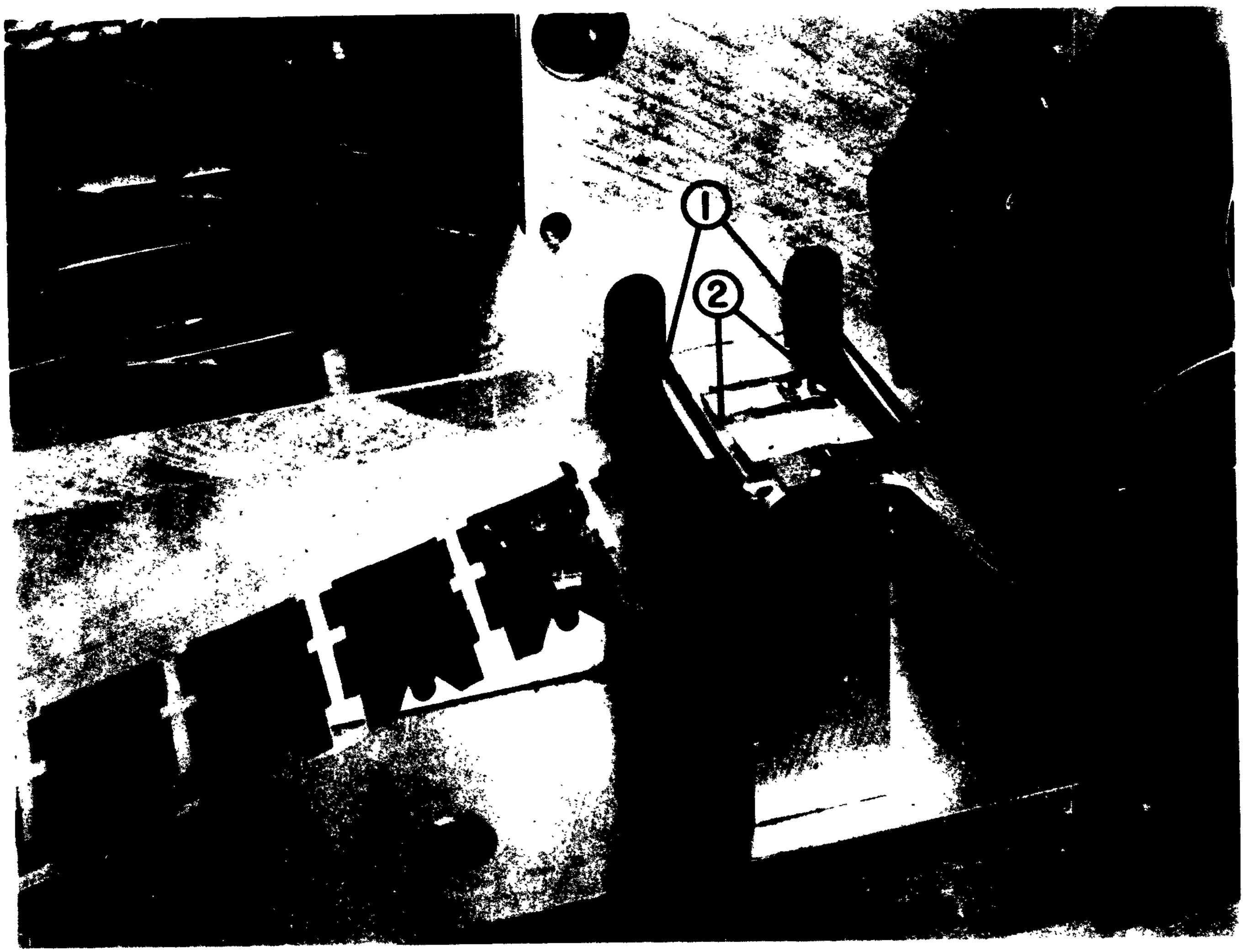
V Evaluation and Conclusion

The Card Packaging Machine is a simple, rugged, hand loaded machine requiring very little maintenance. The ease with which it can be loaded permits an inexperienced operator to reach production speeds in a minimum of time. While training new operators it was found that a brake on the drive motor and an automatic reel winding tension control would be desirable.

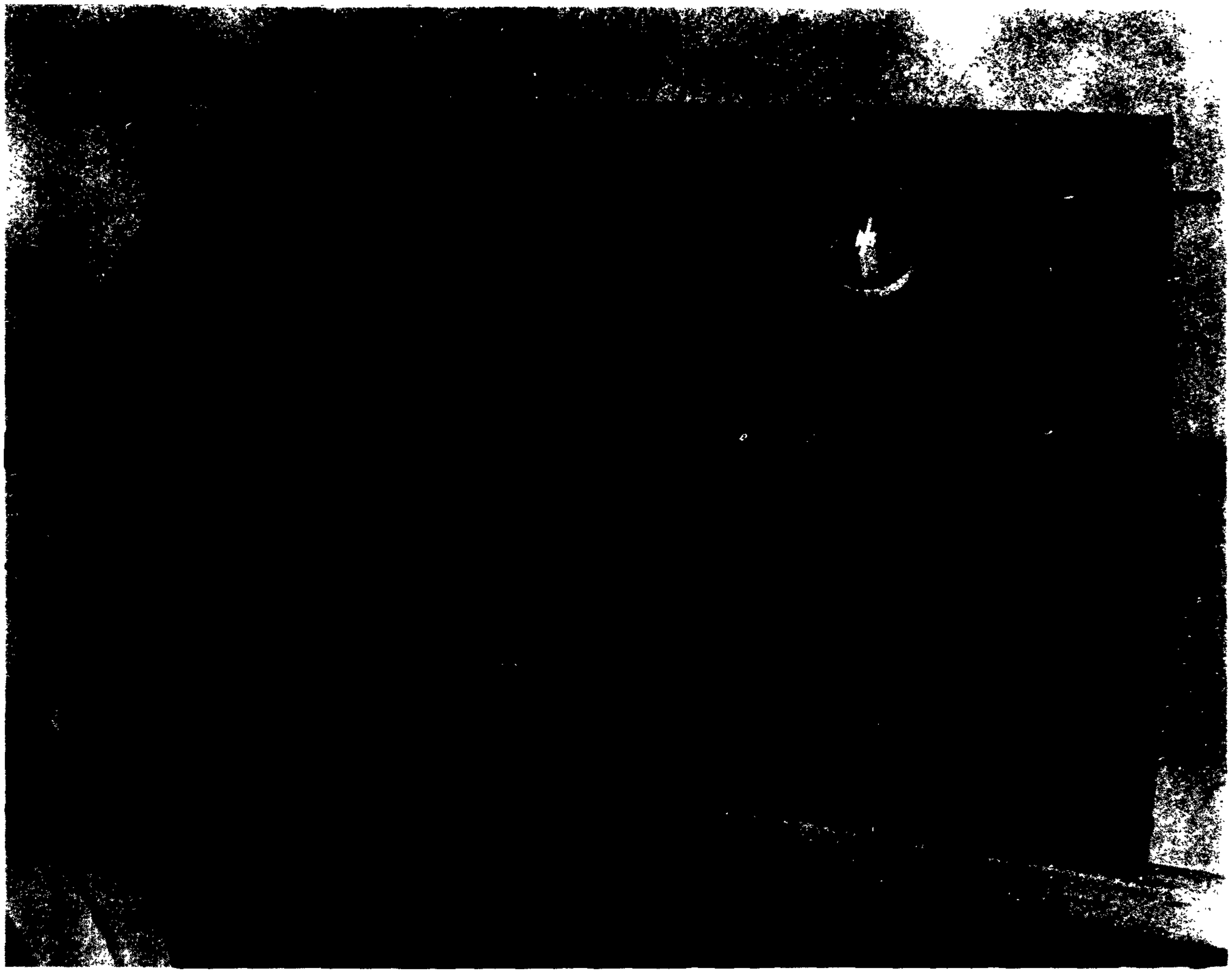
More torque must be applied to the reel as the diameter of the wound belt increases. Through a variable transformer, the operator controls the torque applied to the reel. Periodically, the operator must stop loading to check the applied tension. If too much torque is applied to the belt, the leads of the transistors will be bent; if too little torque is applied, the belt will be wound too loosely or not at all. With the addition of a brake and an automatic reel winding tension control, this Machine will be a trouble-free production machine.



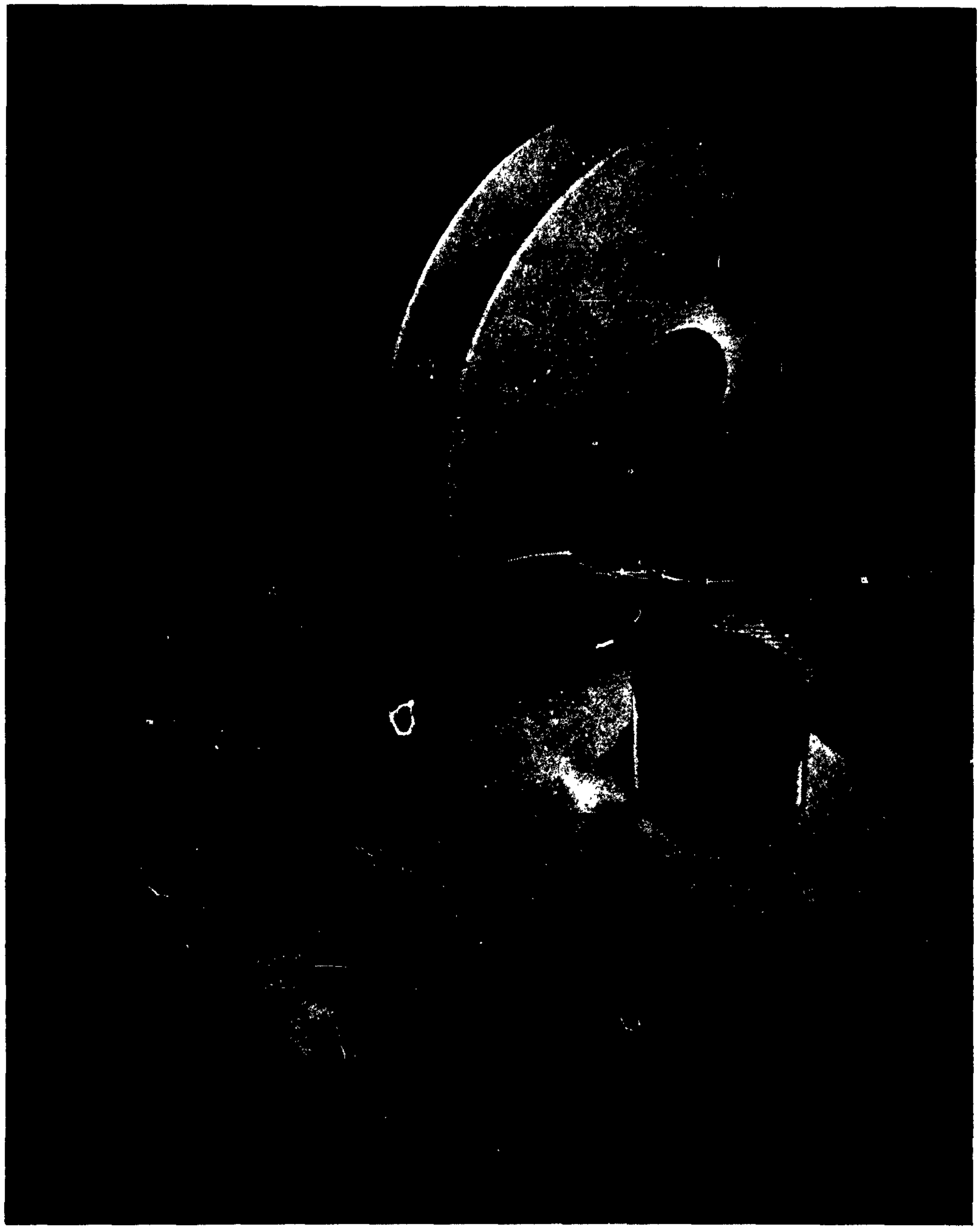
CARD PACKAGING MACHINE
FIGURE 3.20-1



LOADING STATION OF CARD PACKAGING MACHINE
FIGURE 3.20-2



REEL ASSEMBLY MACHINE
FIGURE 3.20-3



SHIPPING REEL FOR BELT LOADED TRANSISTORS
FIGURE 3.20-4

SECTION 3.21

TOOLING FOR CAN PUNCHING AND CODING

J. J. Lorenz

TOOLING FOR CAN PUNCHING AND CODING

I General

Can Punching and Coding is performed on a commercially produced Baird #3-25 multistation transfer press. This machine is custom fitted with the necessary punches, dies and code stamps developed especially for this operation. The machine blanks a basic disc from a continuously fed metal strip, then draws, forms, trims and embosses coded figures on the side of the can in a series of seven successive operations. The parts are carried individually from station to station by means of a reciprocating transfer slide equipped with a series of paired, spring-loaded transfer fingers. A finished part is ejected with each stroke of the press once the initial line has been established. Press output is 4000 pieces per operating hour. Typical markings embossed on cans are shown in Figure 3.21-1.

Inasmuch as the press is a standard model of a well known and widely used commercial item, set-up and operation is achieved using pressworking procedures and techniques generally accepted, and common to the industry. Tool drawings are used as a set-up guide, and accepted tool maintenance procedures are followed. A special operation and maintenance specification has not been provided.

II Press Operating Cycle

Just prior to the press down stroke the loaded transfer slide comes to rest on the right hand limit of its travel. At this point all parts are centralized with respective punches and dies. The parts are then formed on the down stroke. Before starting the upstroke, the unloaded slide moves to the left hand or "pick up" position. While the slide dwells momentarily the press ram returns upward and, with the aid of the lower plungers, all parts are lifted into their respective sets of fingers. The slide then returns to the right hand or "deliver" position and the cycle is repeated. During the "pick up" motion the cam and lever operated punch stripping pads move downward at the precise and appropriate moment to insure retention of the parts in their respective fingers. Punches and pads are then lifted away from the slide.

The fabricating sequence (Figure 3.21-2) on this press is oriented from left to right, with all metal cutting and forming tools being carried downward simultaneously. The raw material is drawn through the disc blanking station by a roll feed system in a direction perpendicular to the line of stations. The blanked skeleton is guided into a scrap drum while the disc is deposited in the first set of fingers, to be carried from station to station until the completed part is ejected.

Disc Blanking Station (Figure 3.21-4) - In the first station the punch blanks the basic disc from the raw material and comes to rest just below the cutting face of the die. A cam operated upper plunger then travels downward through the hollow punch while a cam operated and spring assisted lower plunger simultaneously travels upward. The disc is sandwiched between the plungers and carried down to the part-holding notch in the fingers. The plungers are withdrawn simultaneously, leaving the disc in the fingers ready for delivery to the next station. (Note that in this station the raw material is introduced and blanked <u>above</u> the transfer slide. All subsequent operations are performed <u>below</u> the slide as described in the preceding paragraph on the press operating cycle).

Draw Stations and Sizing Station (Figure 3.21-5) - In a typical draw station the punch carries the part downward into the die, forming the desired cup. The part, held between the punch and the lower plunger, is then returned upward into the slide where it is stripped from the punch and deposited in the fingers. All draw stations and the size and bump station follow this pattern except that the stripping pad in the first draw station is spring loaded and functions also as the blank holding pressure pad. A spring loaded pin built into the draw punch assists in depositing the drawn cup in the fingers. All other stripping pads are cam and lever operated and each is set to strip the part at a precise moment and height according to the needs of the particular station.

In the size and bump station the punch is shouldered and the die face is shaped to form the flange to the desired angle at a specific distance from the bottom of the cup. Station operation is, for practical purposes, identical to that of a draw station.

Flange Trimming Station (Figure 3.21-6) - The tooling in this station is designed to perform two major functions: trim the part, and dispose of the trimmed scrap. Observe, initially, that a stack of scrap trims is always present on the punch body. As the punch travels downward the spring loaded pilot enters the cup before contact is made between the stack of trims and the bevelled finger surfaces. This prevents premature shifting of the cup as the trims force the fingers apart. The pilot now recedes into the punch (lower plunger spring overpowers the lighter punch pilot spring) and the punch drives the part down into the locating nest and die. The critical locating function (for flange concentricity) is left to the nest since, in the absence of a stripping pad, sufficient clearance must be maintained between the pilot and can diameters to permit free exit of the pilot.

With each stroke of the press the stack of trims is forced upward into the trim cutting blade. The cut trims are spread by this blade as they flow upward in a curved path towards the back of the punch where they transfer onto an attached rod. From the rod the trims drop into a pan attached to the machine.

As the trimmed cup is being returned to the transfer slide a special pad (not shown in the sketch), moving in unison with the punch, delays the closing of the fingers until the punch tip has reached a safe height. In this way the cutting edge is preserved and the danger of peeling trims from the punch is eliminated. Here again the spring loaded pilot retains the cup until it is securely held by the fingers.

Code Stamping Station (Figure 3.21-7) - In this station the principle of the tapered draw collet is utilized to convert vertical motion of the press into the radial motion necessary to mark the can. The code stamps (See Figures 3.21-8 and 3.21-9) form a segmented ring, and are suitably mounted in a specially designed collet.

As the press travels downward the mandrel (counterpart of the punch on other stations) enters the cup, driving the cup and lift pin forward until contact is made at the lower shoulder in the collet. Up to this point the collet has remained stationary, being supported by the more heavily tensioned lower plunger. The position of the can now becomes fixed relative to the collet and the collet is forced downward causing the segments to converge and mark the can.

On the return or upstroke, the lower plunger lifts the collet causing it to open and release the can. Actual lift out of the can does not occur until the retreating mandrel permits the collet to open to its maximum dimension. The part is then lifted into the slide where it is stripped from the mandrel and deposited in the fingers. The slide delivers the can to the next (ejection) station where it is pressed from the fingers into a tube which guides it to a pan located at the base of the machine.

III Tooling Development

During the early stages of development of the balanced mechanized line a tubulated can was considered. Experimental tooling was developed and a small quantity of tubulated cans was submitted for evaluation. The advent of the gettered transistor eliminated the necessity for the tubulation, so designs were re-developed and a set of tools constructed.

The problems encountered were, in the main, of a nature common to this type of fabrication. The code stamping phase, however, introduced a need for a greater than average degree of control over the can diameter. The fit between the supporting mandrel and the inside diameter of the can must be held to a .0001 to .0004 inch slip fit to produce a uniformly marked, non-distorted can. A distorted can, or one which is not uniformly embossed, will introduce uncertainties in subsequent mechanical handling and locating operations.

IV Transfer Press vs. Progressive Die

There are certain distinctions to be noted between a progressive fabrication on a transfer press and one performed on a single action press in the more commonly pictured progressive die. Whereas in the average progressive die all tooling is attached to or contained within the die set and the total operation is controlled by the simple movement of the press ram, certain components of transfer press tooling are attached to the machine itself and can be positioned, timed and synchronized to suit the needs of each particular station. In this way superior dimensional refinement and control can be achieved and maintained throughout the run. Maintenance and replacement on a conventional progressive die almost invariably necessitate removal of the total tool, an operation which is usually cumbersome and time consuming. On the transfer press these functions are performed on an individual station basis, and all tools are readily accessible and easily removed.

A host of operations, particularly in the area of flange forming and coining are not readily performed on conventional progressive dies due to their inability to retain the part once it has been cut from the strip. The individual part carrying feature of the transfer press removes this limitation.

V Evaluation

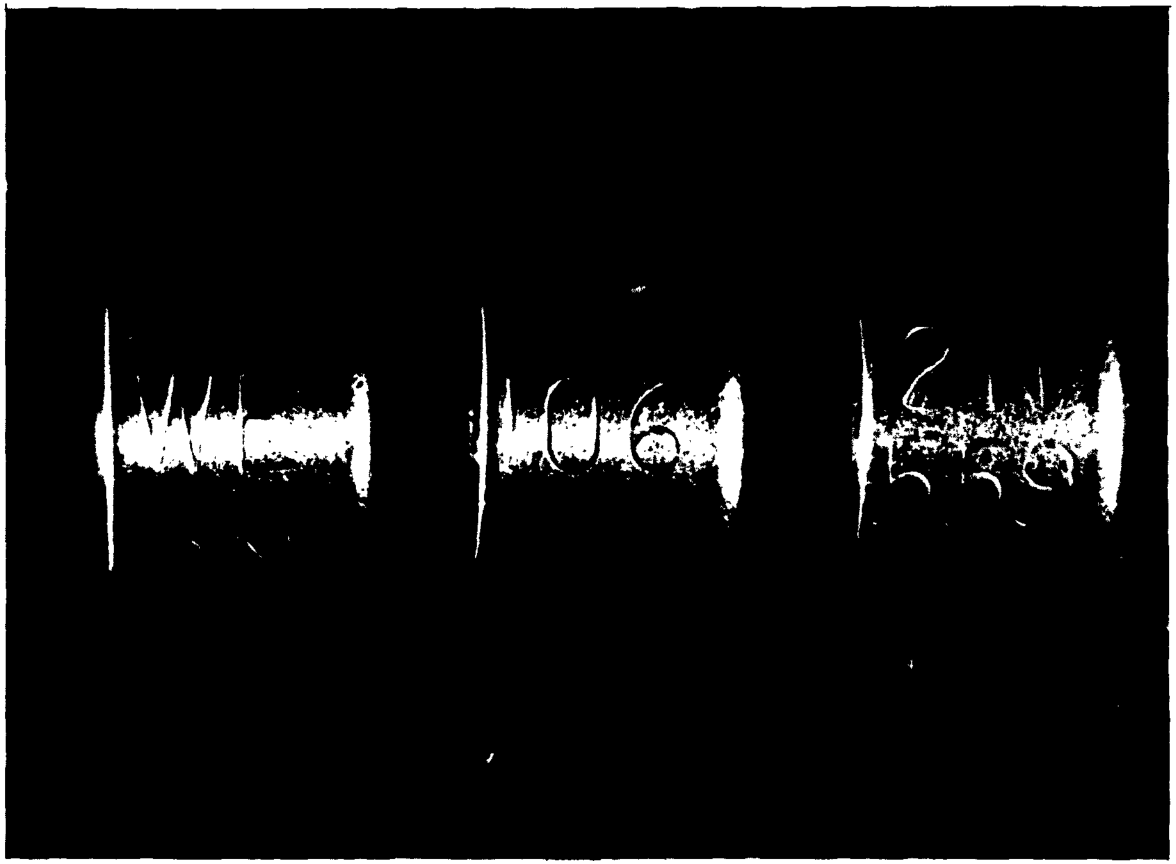
In applying this method of marking, certain other effects and limitations must be considered. Fluctuations in transistor assembly yields create a can ordering problem since the lot size will vary from one dating period to the next (see Figure 3.21-1 and observe the number 106). Sudden improvement in yields results in a surplus of cans of a particular date, while a drop in yield results in a shortage. Markings, such as the acceptance date, placed on the can after device completion still require another marking operation.

Code stamp costs and delivery intervals also have their effect on the economy and efficiency of this method of marking. At a cost of $25 to $35 per code stamping segment and a delivery interval of from four to six weeks, a sufficient inventory of code stamps must be maintained to insure continuous production. Unused date stamps become worthless upon expiration.

Readability of marking made in this manner is somewhat poor. Although the stamping is distinct, lack of contrast between the markings and the adjacent can wall renders lettering of this small size difficult to read with the unaided eye.

VI Conclusion

Can punching and coding is efficiently performed on a commercially available transfer press, using special tooling which follows conventional design patterns. A specially designed set of tools performs the code stamping operation. Parts are produced at the rate of 4,000 pieces per operating hour, with some special attention being necessary to maintain a greater than average accuracy in certain tool dimensions. Code markings are distinctly formed but difficult to read due to lack of contrast. Certain final markings must be accomplished by other means in later stages of device manufacture. Lot sizes for coded cans must be carefully predetermined due to the dating feature of the code, while a sufficient inventory of code stamps must be maintained to insure adequate and continuous production.



TO-18 CAN WITH EMBOSSED MARKINGS (10X MAGNIFICATION)
FIGURE 3.21-1

SEQUENCE OF OPERATIONS

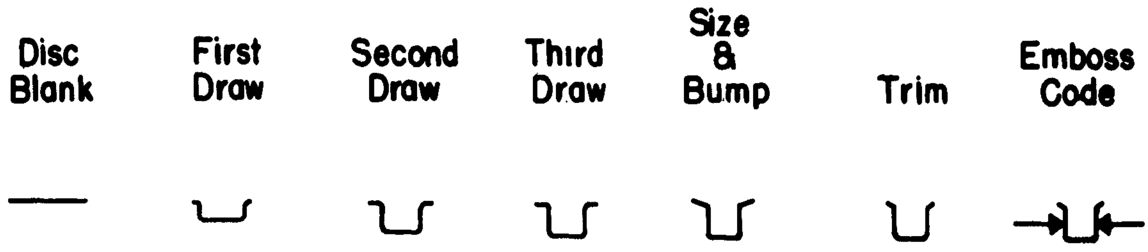


FIGURE 3.21-2

TYPICAL TRANSFER FINGERS IN SLIDE

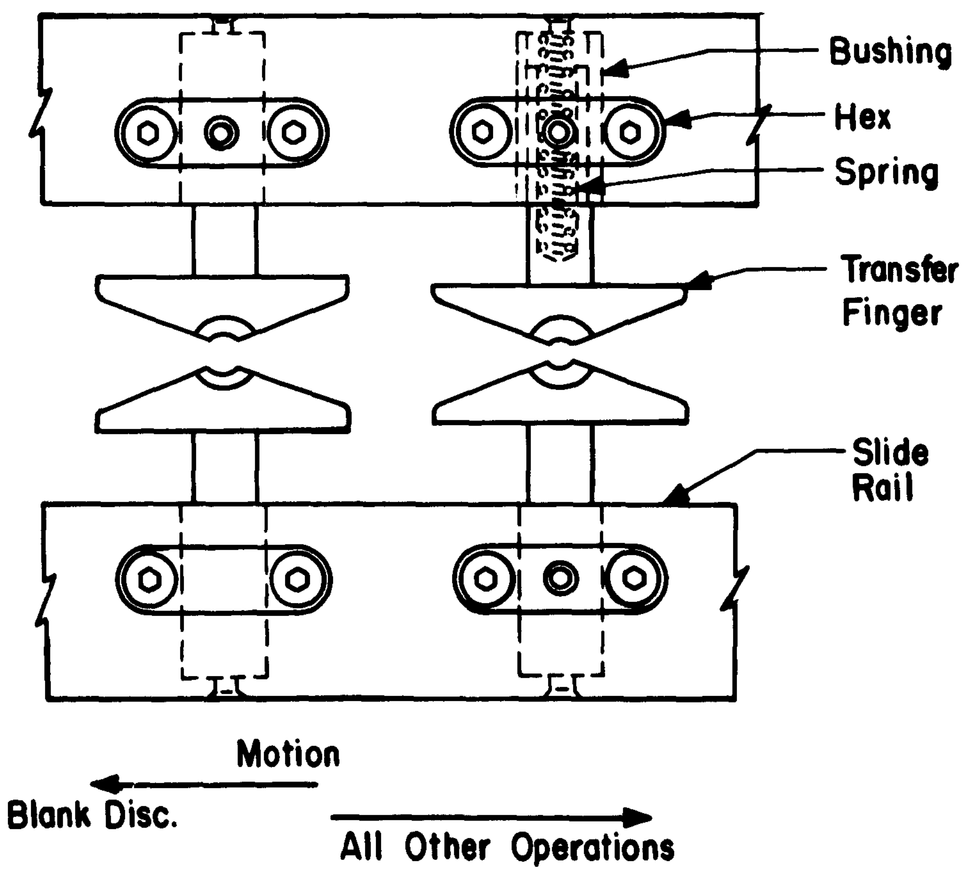
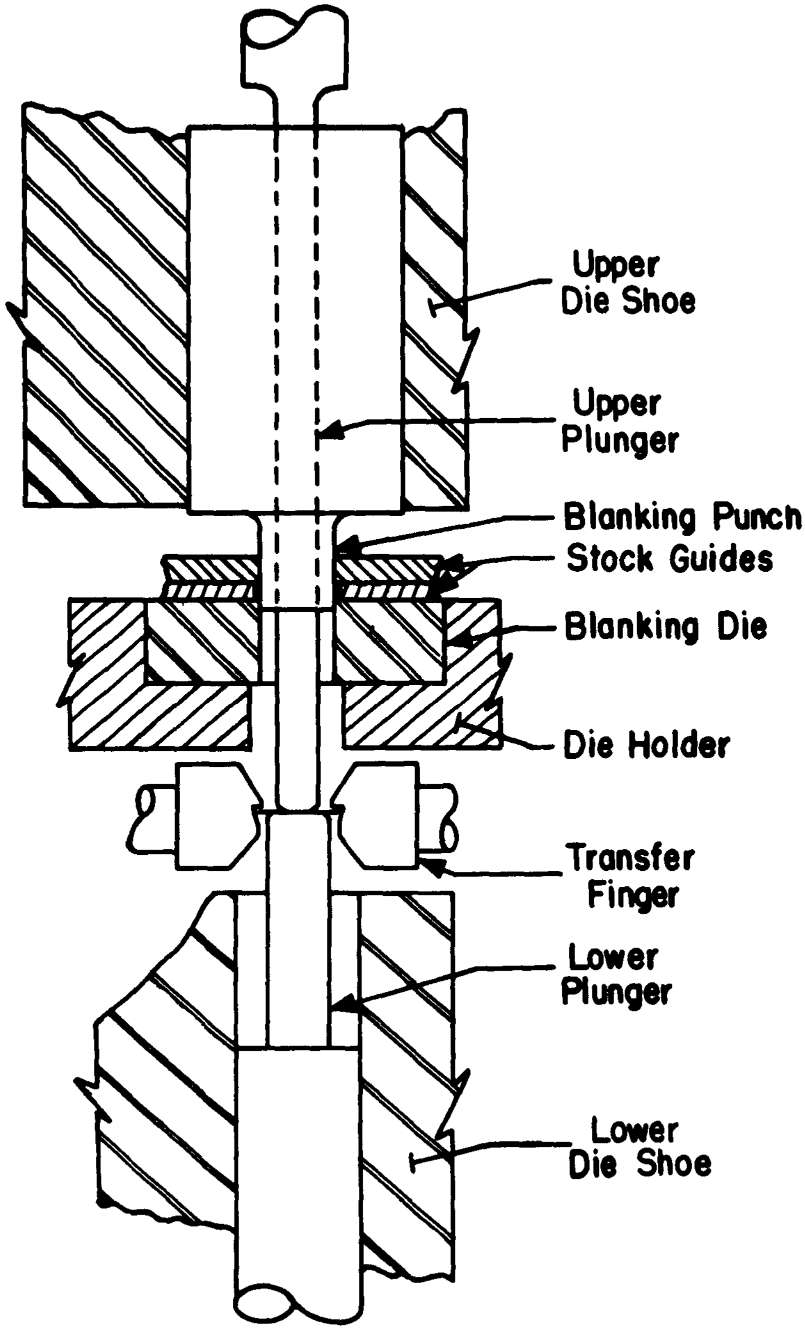


FIGURE 3.21-3

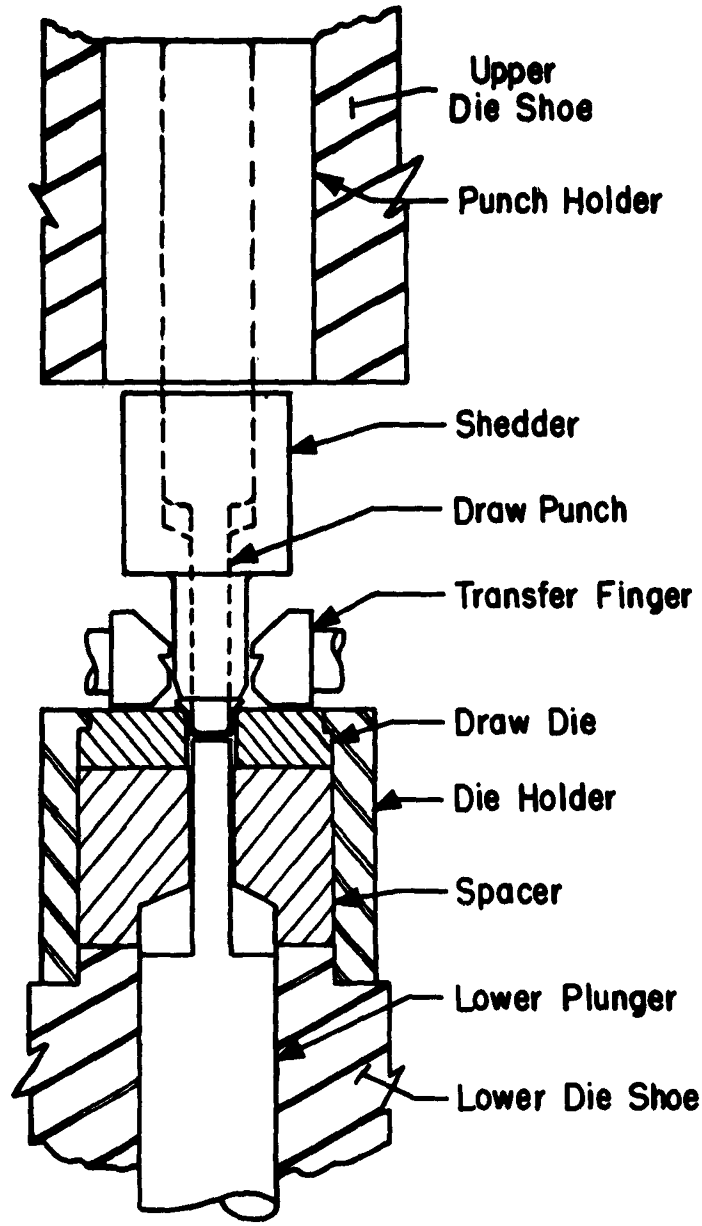


DISC BLANKING STATION

FIGURE 3.21-4

OPERATION:

DISC IS BLANKED FROM RAW MATERIAL STRIP AND LOWERED INTO TRANSFER FINGERS THROUGH COORDINATED MOVEMENT OF UPPER AND LOWER PLUNGERS. PLUNGERS RETRACT AND PART IS CARRIED TO NEXT STATION.

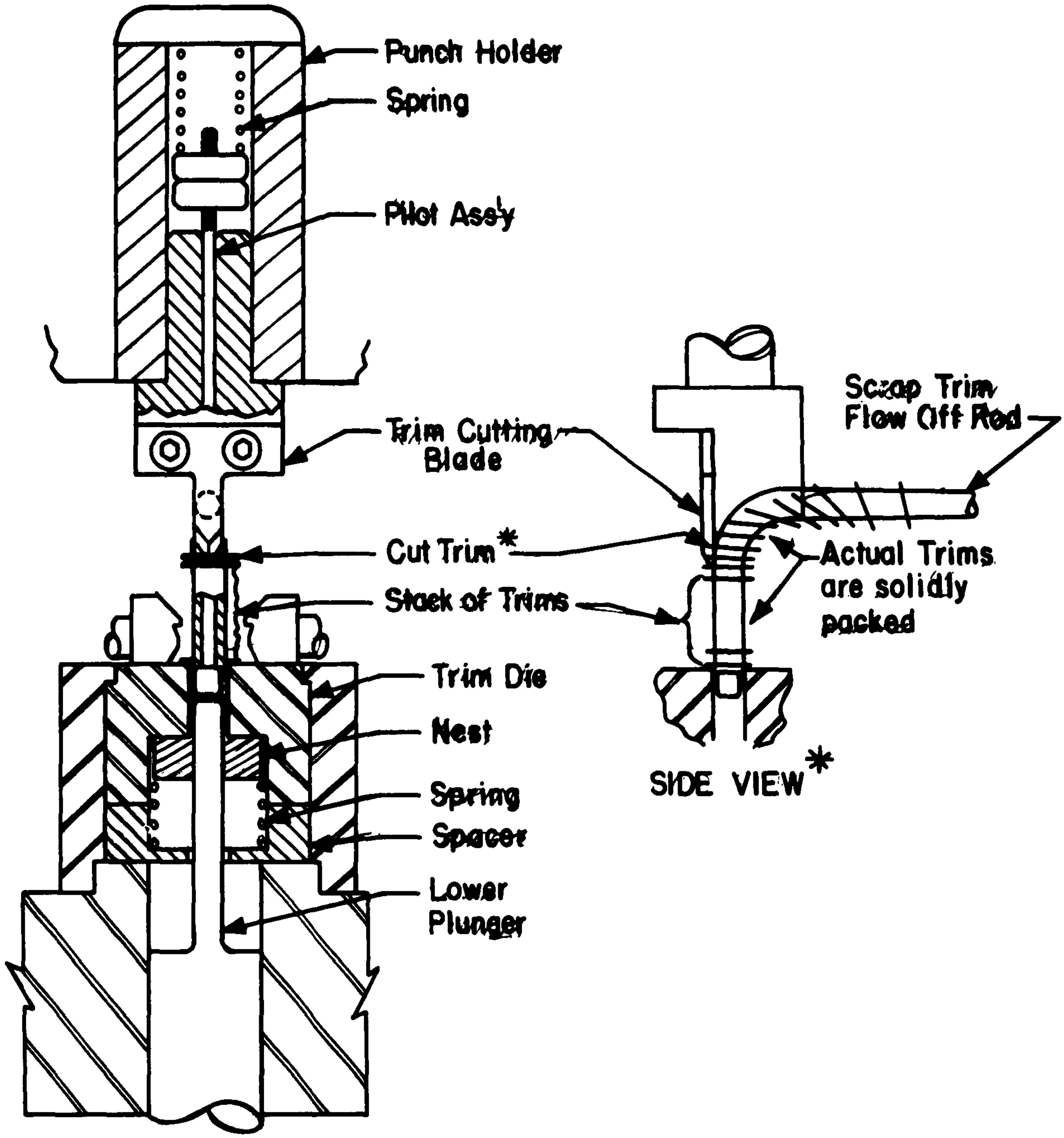


TYPICAL DRAW STATION*
FIGURE 3.21-5

* OPERATION:

PUNCH CARRIES PART DOWNWARD INTO DRAW DIE. ON RETURN, LOWER PLUNGER FOLLOWS PART AND PUNCH UPWARD WHERE SHEDDER STRIPS AND DEPOSITS PART IN FINGERS. PART IS CARRIED TO NEXT STATION.

THE SIZE AND BUMP STATION IS SIMILAR IN CONSTRUCTION AND OPERATION EXCEPT THAT A STEPPED PUNCH SIMULTANEOUSLY BUMPS BOTTOM OF CUP AND OUTER FLANGE, THUS SIZING HEIGHT OF CUP AND FORMING FLANGE TO THE DESIRED ANGLE.



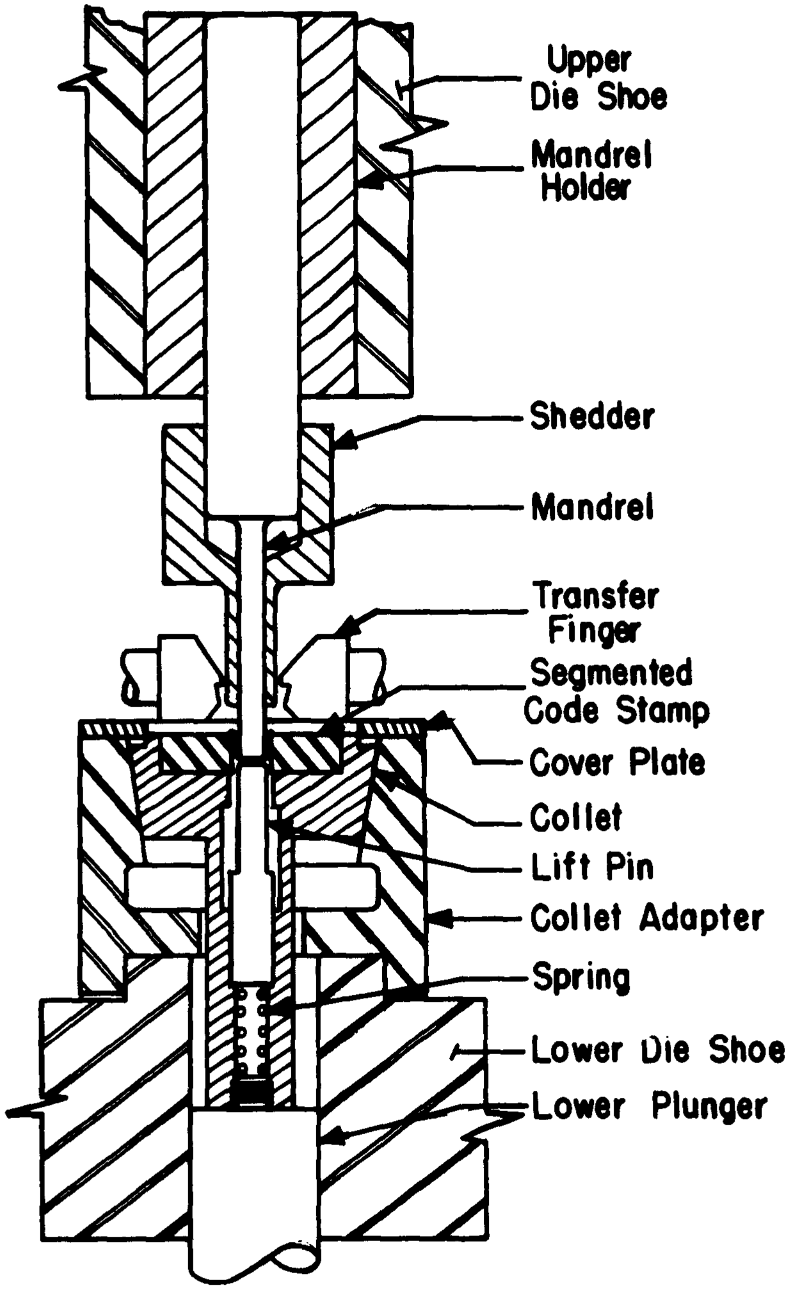
TRIM STATION

FIGURE 3.21-6

OPERATION:

PILOT AND PUNCH CARRY PART DOWNWARD INTO NEST AND DIE. ON RETURN, FINGERS ARE KEPT OPEN UNTIL PACKED TRIMS CLEAR FINGER NOTCHES. SPRING LOADED PILOT DEPOSITS PART IN FINGERS.

* DURING THE OPERATION, STACK OF TRIMS IS GRADUALLY FORCED UPWARD AGAINST TRIM CUTTING BLADE. CUT TRIMS FLOW OFF ALONG SHAFT ATTACHED AND BLENDED TO UPPER BACK PORTION OF PUNCH.

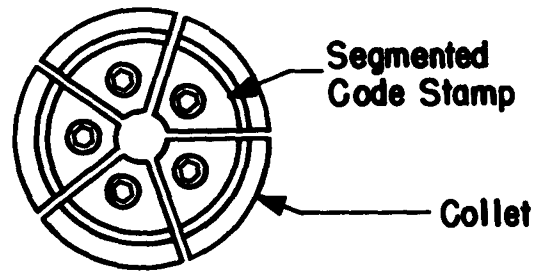


CODE STAMPING STATION

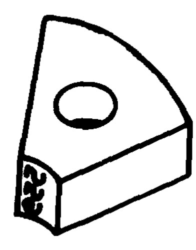
FIGURE 3. 21-7

OPERATION:

MANDREL ENTERS AND DRIVES CAN DOWNWARD UNTIL CONTACT IS MADE BETWEEN LIFT PIN AND LOWER SHOULDER IN COLLET STEM. AS MOTION CONTINUES COLLET IS COMPRESSED AND CAN IS EMBOSSED. COLLET RETURNS UPWARD, OPENS, AND RELEASES CAN. SHEDDER STRIPS AND DEPOSITS EMBOSSED CAN IN FINGERS.



CODE STAMPS IN COLLET
FIGURE 3. 21-8



TYPICAL CODE STAMP
FIGURE 3. 21-9

SECTION 4

DISCONTINUED DEVELOPMENTS

Changes in requirements and planning caused deletion of seven mechanization developments during Phase 1 of this contract. The following five developments were discontinued early in the mechanization program before design began:

Gaging Germanium Slices

Electrolytic Wafer and Mesa Preparation

Constrained Pinch-Off

Pinch-Off Protection

Gold Wire Preparation

The first 2 operations - Gaging Germanium Slices and Electrolytic Wafer and Mesa Preparation - were among the 14 operations originally contracted for 2N559 mechanization. Mechanization developments for the other 12 operations were completed and machines built. The development for Gaging Germanium Slices was discontinued while design criteria were being established. At that time, it was learned that a lapping machine manufacturer had undertaken an identical development. A machine incorporating the desired features was expected to be available in late 1959.

Feasibility studies for Electrolytic Wafer and Mesa Preparation were begun, but machine development was not completed. Development was delayed because the process was not proven or established firmly enough to proceed. In early 1960, a decision to moat etch 2N559 slices eliminated the need for any further development of the Wafer and Mesa Etching operations.

Adoption of the present non-tubulated can eliminated the need to mechanize either the Constrained Pinch-Off or the Pinch-Off Protection operations. A feasible means of mechanizing the Pinch-Off Protection operation was established before the tubulated can was eliminated. An earlier design change had made the Constrained Pinch-Off method of sealing tubulations unrealiable and required development of the Pinch-Off Protection operation.

At one time, the Contract listed Gold Wire Preparation as an operation to be mechanized. A need for mechanizing this operation certainly existed at inception of the Contract; however, this development was never started. It was delayed pending final development of the Wire Bonding operation. Gold Wire Preparation was not needed after Stitch Wire Bonding was proven feasible as this bonding technique supplies small diameter gold wire directly from a spool thus eliminating prior preparation of the gold wire.

Reductions in production requirements for Nike Zeus brought about deletion of 2 prototype machines as well as 12 duplicate machines. No construction work had begun on the duplicate machines before deletion. Development of the 2 prototype machines had advanced into the design stage before being discontinued. Sections 4.1 and 4.2 summarize the development work that was performed before the 2 machines - (1) Coating and (2) Testing and Date Stamping (2N1094 - 2N1195) - were deleted.

SECTION 4.1

COATING

C. A. Lowell

COATING

I General

The mobile environment of modern electronic apparatus requires the complete protection of transistors from atmospheric exposure. Reliable and permanent performance of the device must be assured under all conditions. The purpose of the semiconductor is defeated unless the fragile members beneath the cover are effectively sealed against possible decay or destruction from external attack. Fungus proof varnish provides part of the necessary protective coating for finished transistors.

Plans for a Coating Machine designed especially for 2N559 and 2N1094 transistors were abandoned after completion of the design phase. The operation will now be accomplished on the 2N560-2N1051-2N1195 Painting and Coating Machine which is described in the Final Report of Contract No. DA-36-039-SC-81294. The program associated with the deleted machine is discussed in the following report.

II Process Requirements and Machine Design

Transistor coating is a fluid finishing process using a technique similar to spraying paint. Fungus proof varnish is used as the coating agent and its application must satisfy the following requirements:

1. Complete coverage of the can to header welded junction and the underside of the header over the glass-to-metal seals of the leads and platform.
2. Coverage of the can sides is permissible, but not required on the can tops.
3. Uniformity of coating - no dripping or excessive varnish

running down the leads or sides of the can.

4. Maximum coverage of leads - 5/32 inch measured from the flange bottom.

5. Maximum can diameter after coating - .190 inch.

The proposed Coating Machine specifications designated a magnetic tray handling system for transistor supply and transport. Each magnetic tray holding 30 transistors is a functional part of a transport magazine that holds 20 magnetic trays.

The finalized Coating Machine design concept provided a shuttle type conveyor to carry transistor trays from the supply magazine, through a spray coating booth and into an empty storage magazine. To accomplish this process the following features are incorporated in the completed design:

1. A precision chain conveyor is held in accurate alignment by rigid retainers. Receptacles for transistor trays are attached to the chain members and transport the trays through the machine. Spring loaded clamping mechanisms hold the trays firmly in the receptacles.

2. Loading and unloading of the conveyors is automatic. Magnetic trays full of transistors are loaded into the conveyor receptacles from a supply magazine located at one end of the conveyor, and unloaded, after coating, into an empty transport magazine as the conveyor passes the entrance to the magazine. Air cylinder action is used to position the trays in each instance.

3. Coating is to be accomplished by two automatic spray guns located on opposite sides of the trays and directed downward, but staggered to prevent covering undesirable

areas by the turbulence of two converging sprays. Varnish is to be supplied from a two-gallon pressure pot with an air operated agitator.

4. For convenience in spraying the underside of the cans, the transistors are carried through the machine with the headers down. They remain in the magnetic trays, but are lowered before coating to expose the proper area to the spray pattern. Spraying takes place only when the trays are being indexed, since the guns are actuated by a mechanically operated valve that is opened by a lug as the conveyor moves.

5. After coating, the transistors will be raised to their original position in the trays leaving a small gap between header and tray to prevent sticking. Lowering and raising the transistors is a one-shot, ram operation handling 30 at a time.

6. Travelling shields composed of absorbent paper are provided to protect the trays from overspray and to maintain coating tolerance on the transistor leads. The paper shields are synchronized to index clean portions through the coating zone in time with the conveyor index, thus a fresh shield is exposed for each spray cycle.

7. A protective booth surrounds the spray target area and provides ventilation by a down draft system. An unusual feature of the booth is a water filled drawer beneath the conveyor for accumulating varnish overspray.

Planned production output for this Coating Machine is 5,400 transistors per hour, based on the ability to handle and spray coat one trayful every 15 seconds. This forecast assumed that one machine operator could load and unload magazines and maintain overall surveillance of the spray process.

III Development

Automatic transistor coating was initiated on the basis of the expected high production requirements of Nike Zeus. The manual production capacity using a hand loading and spraying technique was 350 units per operator hour. Feasibility studies showed that mechanized coating would multiply the operator's output at least by a factor of 10. Therefore, plans were made to provide a special Coating Machine. An evaluation of proposals submitted by several subcontractors resulted in the decision to purchase the machine design and construction from George L. Nankervis Co., Detroit, Michigan.

Shortly after placing the contract, an engineering review of the mechanization program was conducted with reduced Zeus production quotas in mind. In addition, the finishing specifications for 2N559 and 2N1094 codes had been changed. First, a painting operation was required before coating. Then, the coding operation was changed to an ink stamping technique instead of metal embossing. Finally, the coating process was also revised to include total transistor can coverage. Since a Painting and Coating Machine for 2N560, 2N1051, and 2N1195 transistors was nearly built, the need for the special Coating Machine for 2N559 and 2N1094 transistors was questionable. A study of the Painting and Coating Machine indicated that the coating capacities anticipated for 2N559 and 2N1094 transistors could be handled on this machine by providing conversion tooling. So cancellation of the special Coating Machine was arranged with the subcontractor, who agreed to finish the design phase and halt construction plans.

IV Conclusion

Coating of 2N559 and 2N1094 transistors will be accomplished by providing conversion tooling for the Painting and Coating Machine, Contract No. DA-36-039-SC-81294. Should a seperate machine be needed for this operation, the design drawings are available; however, some modifications to the design would be necessary to conform to the latest coating specifications. A general review of the design concept might also be worthwhile before initiating machine construction.

SECTION 4.2

TESTING AND DATE STAMPING (2N1094)-2N1195)

K. C. Whitefield

TESTING AND DATE STAMPING (2N1094-2N1195)

I General

Initially, two separate machines were contracted for 2N1094 and 2N1195 testing. Later, reduced Zeus production requirements and similarity of electrical tests led to a combination of the two testing operations on one machine, Testing and Date Stamping (2N1094-2N1195). This combination introduced one major problem: development of a compatible handling system for the TO-18 (2N1094) and the TO-5 (2N1195) transistor packages. Finally, before developing a compatible handling system, another change in contract planning led to deleting this development from the Contract.

II Initial Developments

The 2N1094 transistor is a germanium P-N-P amplifier of the same TO-18 size as the 2N559 and has 14 test parameters - 5 D-C and 9 A-C. The original, June 1960 goal of this project was to provide reliable mechanized electrical testing of adequate capacity for 2N1094 transistors on a test set mechanically the same as the 2N559 Testing and Date Stamping Machine, Section 3.18.

Early development effort was concentrated on the electrical test modules - particularly on the two high frequency parameters, 250 mc REh_{ie} and 100 mc h_{fe}. The General Radio 1607-A Immittance Bridge was established as a standard. Establishment of this standard led to recognition of the effects lead length and contacting the leads with test probes had on the test readings.

While this development was in process, design was started on five D-C and four "h" parameter test modules. Drawings were released to construction in June 1961. At this time, however, a change in Zeus production planning made it desirable to consider combining the 2N1195 testing with 2N1094 testing.

The 2N1195 transistor is a TO-5 size germanium P-N-P amplifier with many of the same parameters as the 2N1094. The 2N1195 Final Electrical Testing Machine development had previously been part of Contract No. DA-36-039-SC-81294 on which plans had been to have it follow the mechanical design of the 2N560-2N1051 D-C and Switch Testing Machine with suitable regard for the high frequency FEh$_{ie}$ and h_{fe} tests.

III Final Developments

Combining the TO-5 size (2N1195) transistor with the TO-18 size (2N1094) transistor, however, caused a major mechanical revision in the 2N1094 Testing and Packaging Machine. Captive test sockets each with a mechanical test memory mounted on an in-line conveyor had been proposed when this project was halted in October 1961. At this time consideration was being given to combined line testing machines having multi-code test capability. Mechanical design of the combined Testing and Date Stamping Machine (2N1094-2N1195) only reached the tentative layout stage.

When this project was halted, the design stage was completed and construction was in process on the following D-C and 1 kc "h" parameter test modules: BV_{CEO}(pulsed), BV_{CBO}, BV_{EBO}, I_{CBO}, h_{FE}, h_{ob}, h_{rb}, h_{fb}, and h_{ib}. These designs provide separate slide-out chassis to facilitate maintenance in the test cabinet and individual power supplies to facilitate replacement and bench testing.

IV Conclusion

Under current Zeus production planning, currently available D-C and "h" parameter test sets will provide adequate testing capacity for these parameters; other 2N1094 and 2N1195 electrical tests will be checked on manual equipment.

Since discontinuing machine development in October 1961, further effort has been restricted to developing mechanizable test modules for the other tests, particularly REh_{ie} and h_{FE} at higher frequencies. These developments are reviewed in the Special Studies part of this report. Testing and Date Stamping (2N1094-2N1195) was formally deleted from the Contract in the contract modification technically accepted December 19, 1962.

SECTION 5

SPECIAL STUDIES

Four special studies were undertaken during the 2N559-2N1094 Mechanization Program. Three studies concern the Wire Bonding operation. The fourth study, High Frequency Testing, involved development of high frequency test modules that are designed for high volume production testing.

Wire bonding problems were analyzed during the special study of Thermocompression Bonding of Small Diameter Wire. This study was undertaken in order that the full potential of the wire bonding machines can be realized. Experimental results re-emphasized the importance of cleanliness in maintaining a reliable, trouble-free Wire Bonding operation.

The study of Centrifuge Testing of Internal Lead Connections of Transistors presents the theory and formulae upon which a correlation was established between a "Pull Test" and a uniformly distributed centrifugal load: A table developed during this study lists the concentrated force required during a "Pull Test" to simulate the reactive forces which wire bonds of various configurations must sustain to survive a centrifugal load of 20,000 g's. Wire bonded devices centrifuged at high G-levels provide visual verification of the theory and assumptions.

Mechanizing the Wire Bonding operation stimulated the Impact Study of Stitch Wire Bonding. This study was needed because the approach speed of the bonding tip was increased by the mechanized operation. It was necessary to determine if the increased tip speed can damage a wafer, and if so, what approach speeds are permissible. During the study, tests were conducted and calculations made. The results indicate that the dynamic forces were within permissible limits.

During the development of the D-C and High Frequency Testing Machine for Device 12, in an earlier Phase of this Contract, an engineering approach evolved for automatically testing REh_{ie} (base spreading resistance) at 250 megacycles. An analysis of construction costs and the anticipated Device 12 production level indicated that it was not practical to develop and build an REh_{ie} module for Device 12. This module and a 100 megacycle h_{fe} (Common Emitter Short Circuit Current Transfer Ratio) module were developed during the special study of High Frequency Testing. The experimental REh_{ie} module has performed satisfactorily while manually testing a large quantity of transistors on a go no-go basis.

Details of these studies and developments are reported in the next four subsections:

SECTION 5.1

SPECIAL STUDIES OF HIGH FREQUENCY TESTING

G. B. Loughery

SPECIAL STUDIES OF HIGH FREQUENCY TESTING

I General

The development work to be described here was initiated to provide methods of making several of the more difficult transistor tests on mechanized test equipment.

In general, high frequency testing is done on elaborate laboratory type equipment, which obviously is not geared to production needs. The use of such equipment invariably produces a bottleneck in the production line. Prior to this development, two serious offenders were:

1. 250 Megacycle Base Spreading Resistance (REh_{ie})
2. 100 Megacycle Common Emitter Short Circuit Current Transfer Ratio (h_{fe})

Also quite important are:

3. Common Base Output Capacitance (C_{ob})
4. Turn-On and Turn-Off Time

A unique solution was found to the 250 mc REh_{ie} problem. The coaxial system, which requires no tuning, nulling, or balancing is described in detail in Section II. A passive coaxial system was also developed for 100 mc h_{fe}. Here again, no operator adjustments are required to obtain a direct readout of the parameter under test.

Since the test requirements for C_{ob} and switching time measurement have been met by existing diode and transistor test equipment, it is felt that these methods can be applied to the mechanized testing of the devices under consideration here.

II 250 Megacycle Base Spreading Resistance (REh_{ie})

As mentioned previously, a new concept was applied to the measurement of REh_{ie}. A General Radio Type 1602-B Admittance Meter with heterodyne detection was used in conjunction with all circuit development to provide a method of adjusting line length and also to keep a running check on actual REh_{ie} values. This Admittance Meter is such that, with a given load impedance and the output (unknown) line length equal to an odd multiple of a quarter wave length at the operating frequency, the reading obtained is Z unknown ÷ 2.5. The base-emitter junction of the device under test is placed at this $(2N-1)\lambda/4$ point and becomes the load impedance, whose value can be read directly on the Admittance Meter by adjusting the pickup loop arms for null and multiplying by 2.5. The collector of the unit under test is A-C short circuited by a $\lambda/2$ capacitively shorted line.

Since the voltage standing wave pattern assumes well defined positions and amplitudes depending on magnitude and phase angle of load impedance, the possibility of breaking into the base line and sampling the magnitude of voltage, suggests itself. Because we are dealing with a load impedance which is predominantly real, it is expected that the standing wave pattern will be essentially that obtained with a purely resistive load. It was found that measurement at certain points in the base line yielded a voltage which was very nearly directly proportional to REh_{ie}. Figure 5.1-1 shows the essentials of the voltage standing wave pattern for several values of load impedance.

As can be seen from Figure 5.1-1, the open circuit case gives a high voltage level at the load plane, while the short circuit case yields a very low voltage. Impedances between zero and infinity yield intermediate voltage levels. The R-F voltage measurement may be made at, or near, the load plane or $n\lambda/2$ away from the load. It is interesting to note that a voltage which is proportional to load admittance may be obtained at odd quarter wave lengths from the load.

Readout is easily accomplished by the use of a $\lambda/4$ shorted stub connected to the desired point of measurement. This stub presents an open circuit to the main base line and therefore has little or no effect on the standing wave configuration in the base line. R-F or direct voltage may be measured in this stub (preferably near the shorted end) by the use of a tee or diode detector, respectively. D-C readout is desirable for our application because amplification or attenuation is easily accomplished. An elementary schematic of the system is shown in Figure 5.1-2, while several curves of REh_{ie} vs. D-C readout are shown in Figures 5.1-3 and 5.1-4. Figure 5.1-3 shows the results obtained using a General Radio socket to measure a wide range of short lead devices. The highest specification limit that we will be concerned with is 150 ohms. However, it was desirable to obtain enough data to determine areas of nonlinearity, and so forth. Note that the open circuit D-C voltage is 56 millivolts - the asymptote. In Figure 5.1-4, part of Figure 5.1-3 is repeated along with data taken with the Jettron and Loranger sockets (Figures 5.1-14, 5.1-15, and 5.1-16) with long lead devices. These long lead measurements were made on the set shown in Figure 5.1-5 while the short lead data of Figure 5.1-3 was taken on apparatus similar to that shown in Figure 5.1-8. The difference in slope (sensitivity) is due to differences in test sets, sockets and lead lengths.

To further explain circuit operation consider several arbitrary values of pure resistance as the load and observe the load plane voltage:

1. $R_L = \infty$, load voltage is at a maximum which we call E_{OC}.

2. $R_L = Z_o$ (In this case 50 ohms), load voltage is equal to $E_{OC}/2$.

3. $R_L = 0$, load voltage is at a minimum, theoretically equal to zero.

4. $R_L = 60$ ohms, load voltage is somewhat higher than in case 2. The phase of the standing wave is that of case 1.

5. $R_L = 40$ ohms, load voltage is somewhat lower than in case 2. The phase of the standing wave is that of case 3.

As mentioned previously, with the practical case; that is, with a load impedance of h_{ie}, there will be a quadrature component of load impedance (almost invariably capacitive). This produces a shift in standing wave position and, therefore, a departure from the ideal case (Items 1 through 5 above); however, this component is usually relatively small compared to the real part and does not pose a serious problem. Slotted line measurements indicate that the magnitude of this shift is about .05 λ, for a representative group of devices. Figure 5.1-9 shows the slotted line set-up used for these measurements.

Shortly after most of the development work was completed, it became necessary to check REh_{ie}, on a Go No-Go basis, on several large quantities of silicon transistors. The developmental equipment was rearranged as shown in Figure 5.1-8 to expedite testing. During this time the operation of the equipment was observed and found to be very acceptable, out-performing the General Radio Immittance Bridges (the only method of measuring REh_{ie} at the time) by at least 4:1. A Bridge set-up is shown in Figure 5.1-7. To date, about 100,000 devices have been checked on the developmental equipment. Figure 5.1-5 shows a version of the REh_{ie} measuring equipment which evolved from earlier development work.

Figure 5.1-6 is a close up of the experimental socket. A workable scheme for making contact to indexing transistor sockets has been developed, and will be discussed later.

Base bias is applied at any point in the base line by means of a $\lambda/4$ capacitively shorted stub. Collector bias is applied at the $\lambda/2$ collector shorting stub. All development work was done using grounded emitter biasing because erroneous results were obtained with grounded base biasing due to emitter to ground impedance. The need for a self-compensating grounded emitter biasing system prompted the design of a bias regulator which maintains V_{CE} and I_C constant. This regulator was used during the production testing to eliminate bias adjustment.

III 100 Megacycle Common Emitter Short Circuit Current Transfer Ratio (h_{fe})

The method of measuring h_{fe}, to be described here, differs from the conventional methods in that a small voltage developed in the output circuit is stepped up in a $\lambda/4$ coaxial transformer, before being measured. Figures 5.1-10 and 5.1-11 show the final circuit design.

A constant R-F base current is supplied to the device under test by a large value resistor (5K to 25K) connected between the generator and the base contact of the socket. This resistor is mounted as close as possible to the socket so that no appreciable current transformation can exist between the resistor and base contact. Since the value of the resistor is high with respect to expected values of h_{ie}, a fairly constant current drive is obtained. The collector "short" can be obtained in several ways, but some of the best results have been obtained by using a 0.01 microfarad capacitor connected as close as possible to the collector contact. The small voltage developed across this capacitor is applied to the low impedance end of a quarter wave section of line. The other end of this coaxial transformer is open circuited. Readout is obtained near the open end of this collector line. Here again, readout may be R-F or D-C depending upon other requirements.

Base bias is applied through a 100 megacycle choke to the base end of the constant current resistor. To eliminate the bias loading effect of this resistor, a capacitor (about 0.01 microfarad) may be inserted in series with the resistor. The collector bias is applied, also through a 100 megacycle choke, to the collector line, as near as possible to the 0.01 microfarad "shorting" capacitor. If D-C readout is desired, it is necessary to use a 0.01 microfarad capacitor to block collector bias from the diode detector. It is then necessary to put a relatively high value resistor (several megohms) across the input of the diode detector to prevent the collector line from charging. Figure 5.1-12 shows results obtained for long and short lead devices. Note that the slope is the same for all socket types.

IV Turn-On and Turn-Off Time

The system which appears most applicable for these measurements is one which was conceived and developed for semiconductors at Laureldale. Basically this method consists of applying a train of adjustable width drive pulses to the base of the device under test; then observation is made of the width of the input pulse required to cause a collector voltage excursion to 90 percent of the possible swing. The width of this input pulse will then equal turn-on time or turn-off time as the case may be. From past experience, it is known that this method can be made compatible with our mechanizable socket assembly.

This system is presently in use in mechanized test sets for diodes and manual test sets for transistors. When (switching time) testing volume requires, this principle can be applied to mechanized transistor test sets.

V Common Base Output Capacitance (C_{ob})

This measurement will be made with test circuitry which was developed at Laureldale some time ago. It consists, mainly, of a Boonton Capacitance Bridge and two synchronized line frequency choppers. The basic circuit is shown in Figure 5.1-13.

The capacitance bridge measures capacitance between its two ungrounded input terminals, exclusive of capacitance from either one of these points to ground. It is therefore possible to run grounded shield coaxial cable of any length and position to a remote test fixture and not be concerned with capacitance from either lead to ground.

A chopper is employed to alternately transfer the high terminal of the bridge from the unknown capacitance (C_{ob}) to an adjustable reference capacitor (C_{ref}). When the chopper reed transfers, the open contact is grounded by other synchronous chopper contacts. In this manner, chopper capacitance is eliminated from the measuring circuit.

Since the bridge alternately "sees" C_{ob} and C_{ref}, its output is a rectangular wave. The amplitude of this wave is proportional to C_{ob} for half the chopper period, then proportional to C_{ref} for the other half. This bridge output is synchronously detected by another chopper (driven in synchronization with the first) and alternately applied to two "storage" capacitors which charge to the peak value of the bridge output. A D-C voltmeter is connected between these two capacitors and reads voltage differential. For Go No-Go operation, it may be desired to use a sensitive relay system in place of the voltmeter. C_{ref} is adjusted for zero indication at the readout, with no device in the socket. In this way all socket capacitance is effectively eliminated.

This system is presently in use in several test sets and is capable of resolution in the order 0.02 to 0.1 picofarads. Here again, it is felt that the method is applicable to a mechanizable socket.

VI Socket Considerations

Several different socketing schemes were applied during the development of the REh_{ie} and h_{fe} test circuitry. The goal was to develop a socket which would be compatible with all test requirements and which could be indexed into contact with successive test modules. Figures 5.1-14 through 5.1-20 show the various sockets used. Figures 5.1-14 and 5.1-15 show a Jettron socket which is mounted against phosphor bronze contact springs. It is mounted in such a position so as to simulate a socket which has been indexed into contact. The extension serves as a lead guide and spacer so that long lead devices can be consistently positioned.

A tubular contact socket arrangement is shown in Figures 5.1-17 and 5.1-18. Lead contact is made by inserting the transistor leads into three lengths of 20 gauge stainless steel tubing which emerge from the bottom of the socket to provide external contacts. The silver plated beryllium copper structure on the side is intended to provide good emitter and collector grounding as close to the device as possible. Collector grounding is accomplished by the coaxial capacitor which contacts the collector tube on the inside and the ground plane structure on the outside. Emitter grounding is accomplished here by allowing the upper end of the grounding structure to contact the emitter lead.

Another experimental socket is shown in Figure 5.1-16. It is quite similar to the socket shown in Figures 5.1-14 and 5.1-15 except that a Loranger 2293 socket was used.

The socket that appears most promising is the configuration shown in Figures 5.1-19 and 5.1-20. It consists of a modified General Radio socket with two phosphor bronze contact strips mounted directly on special center conductors, and a third strip mounted on the shell of the socket. The 0.01 microfarad capacitor is in place for 100 megacycle h_{fe} measurements.

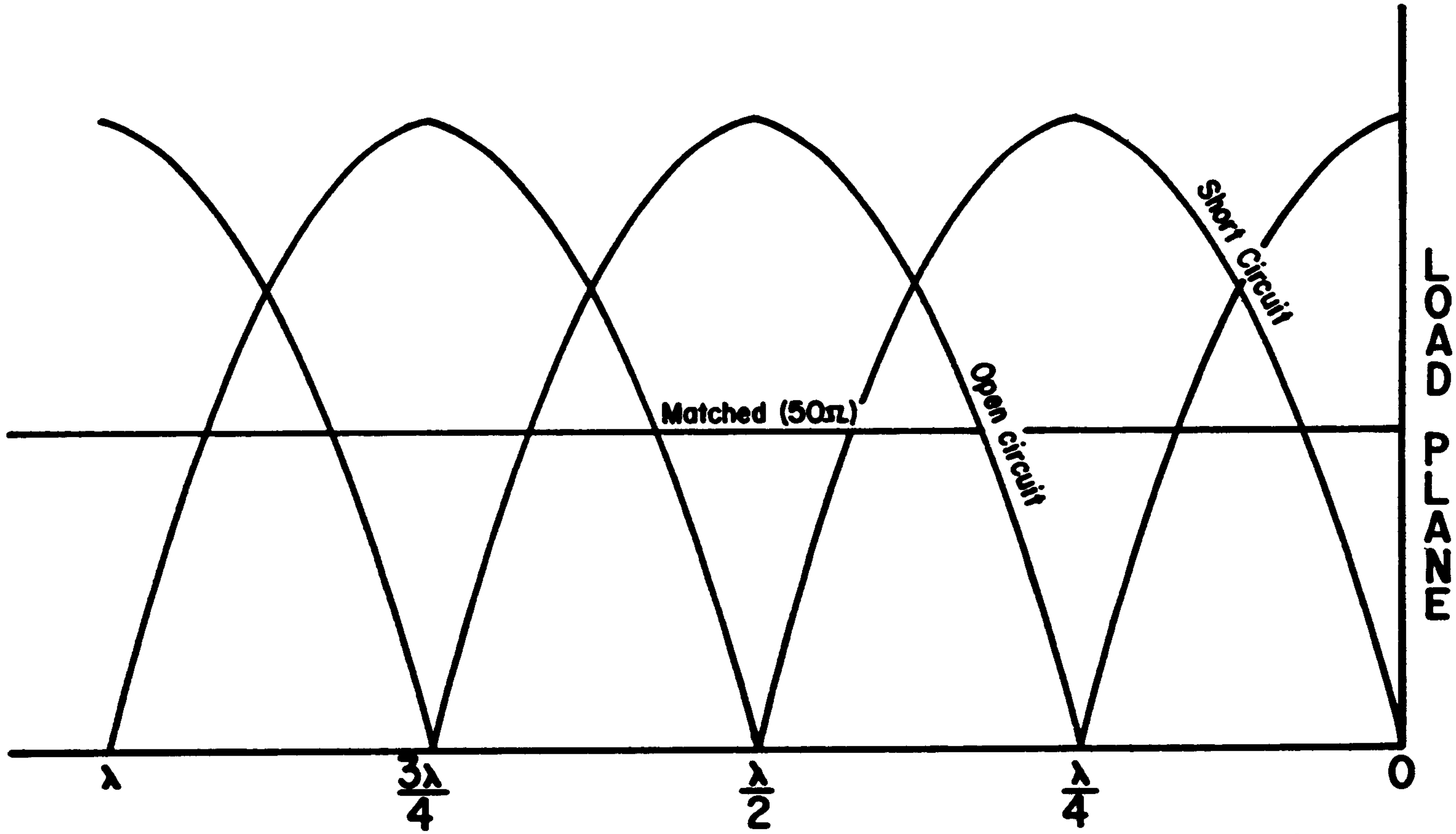
VII Conclusion

In reviewing the curves it can be seen that the REh_{ie} equipment gives excellent correlation for practically all types of devices. Minor discrepancies are caused by phase shift, as mentioned previously, and also certain inaccuracies in the actual values of REh_{ie}, as obtained on the General Radio Immittance Bridge. This bridge is subject to errors of the order of 5 percent for this measurement.

The correlation exhibited by the h_{fe} circuitry is fairly good, with the relatively wide deviations being partly explained by the fact that the Immittance Bridge accuracy is about 10 percent for this measurement.

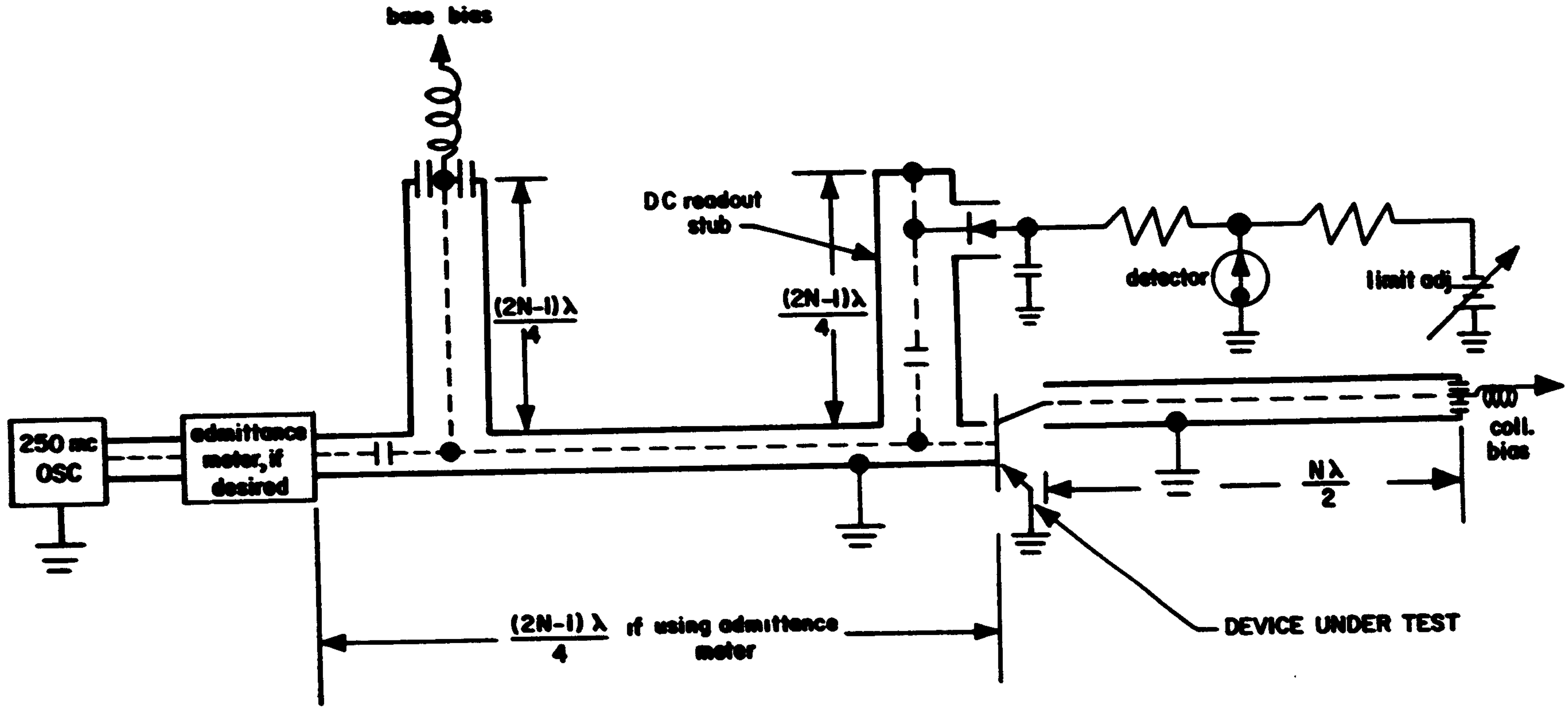
Although only Go No-Go operation is required of the several test circuits, it is possible to get direct readout of actual values from all of these circuits. C_{ob} and switching time modules should be most accurate (while REh_{ie} and h_{fe} follow, apparently in that order).

It is obvious that there is a great need for better high frequency sockets, especially one which will accept long lead devices. Although good correlation was obtained for both long and short lead devices, best results are obtained when the measurement can be made about 1/4 inch from the header.



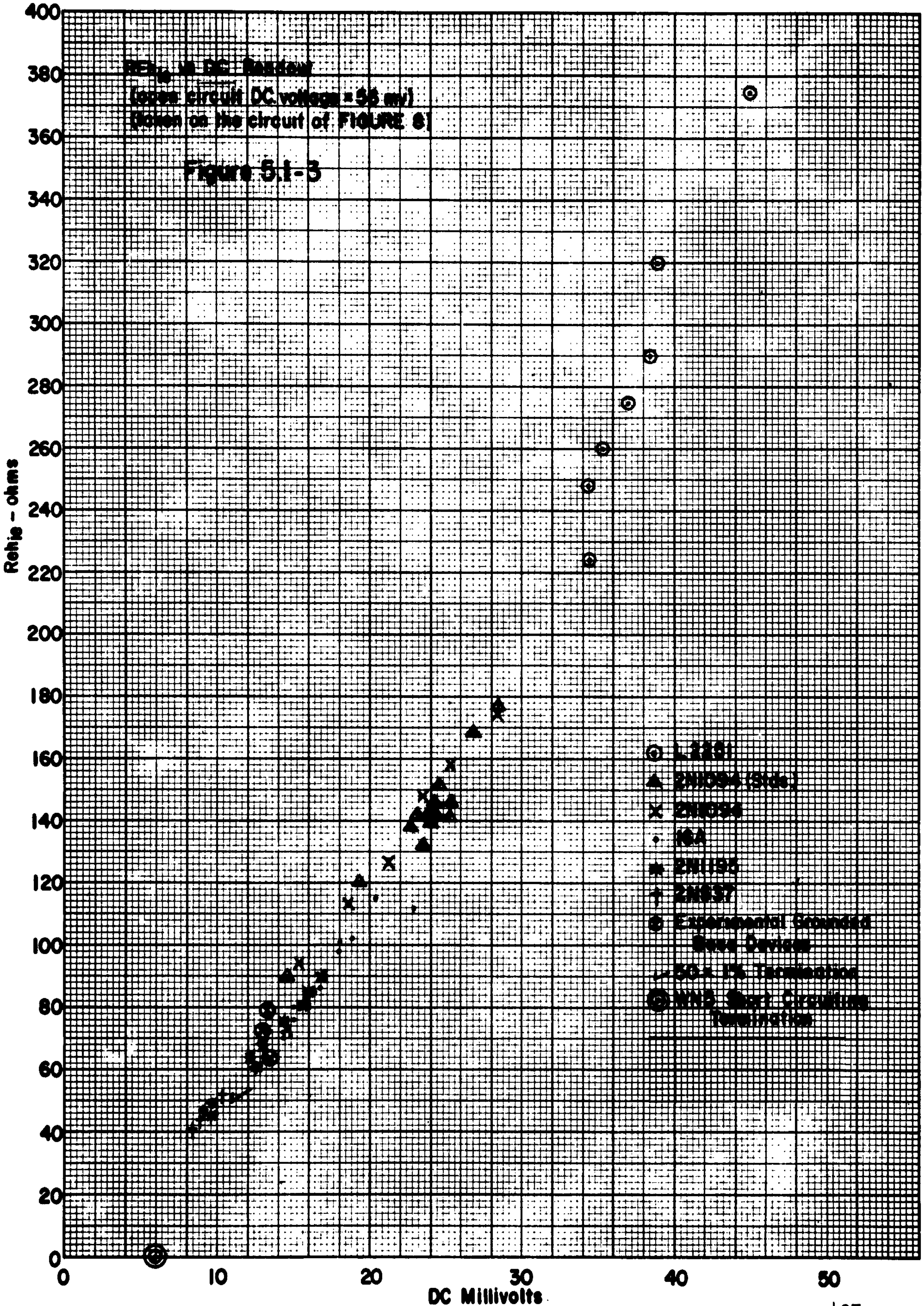
Plot of voltage standing wave amplitude for $R_L = \infty, 50\Omega, \& \ 0$

FIGURE 5.1-1



Basic Circuit for Go No - Go Testing of REh_{ie}

FIGURE 5.1-2


(open circuit DC voltage = 56 mv)
(taken on the circuit of FIGURE 6)
Figure 5.1-3
Rehig - ohms
DC Millivolts
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
10
30
50
2N1094 (Stds.)
2N1094
16A
2N1195
2N637
Experimental Grounded Base Devices
50 Ω 1% Termination
WNB Short Circuiting Termination

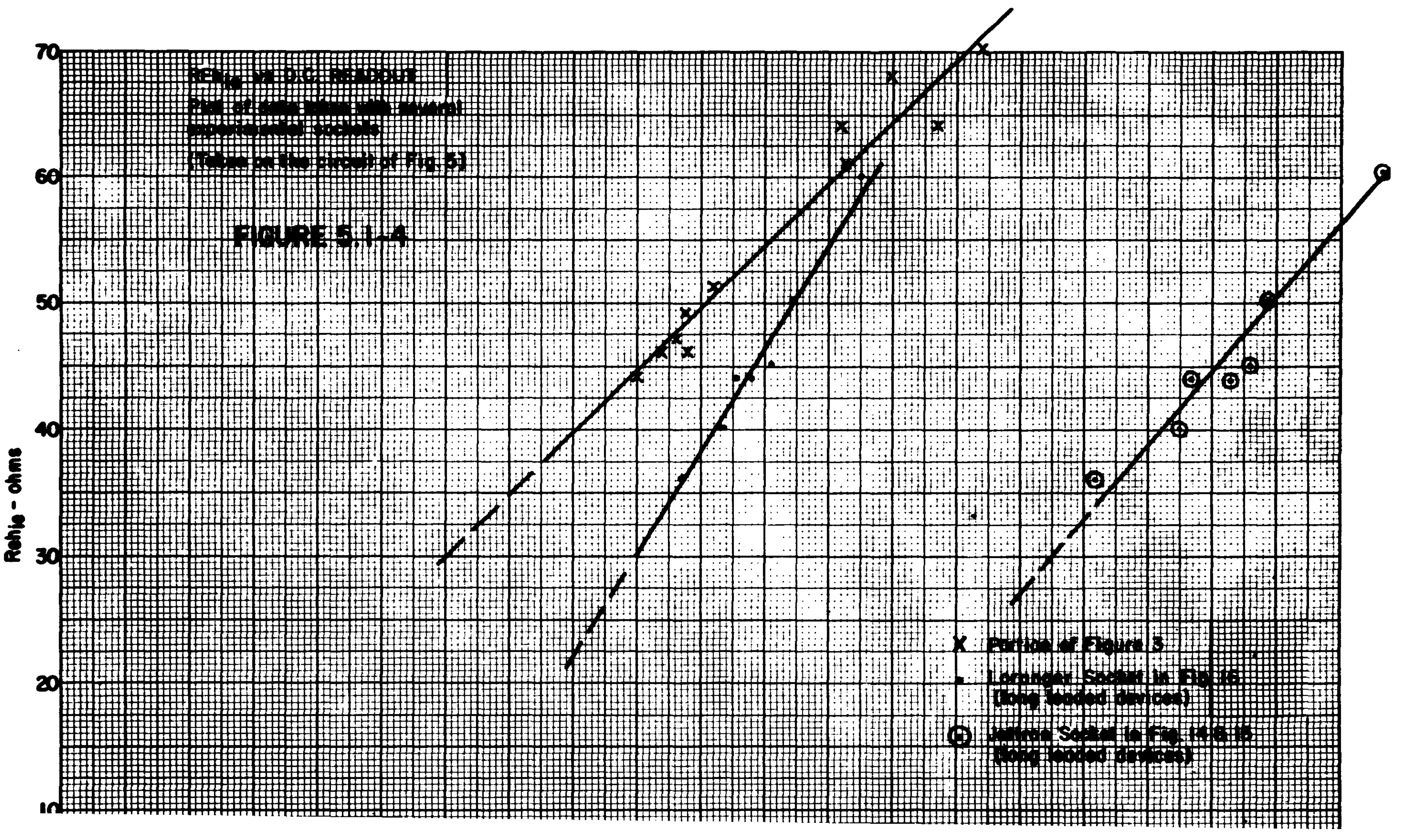
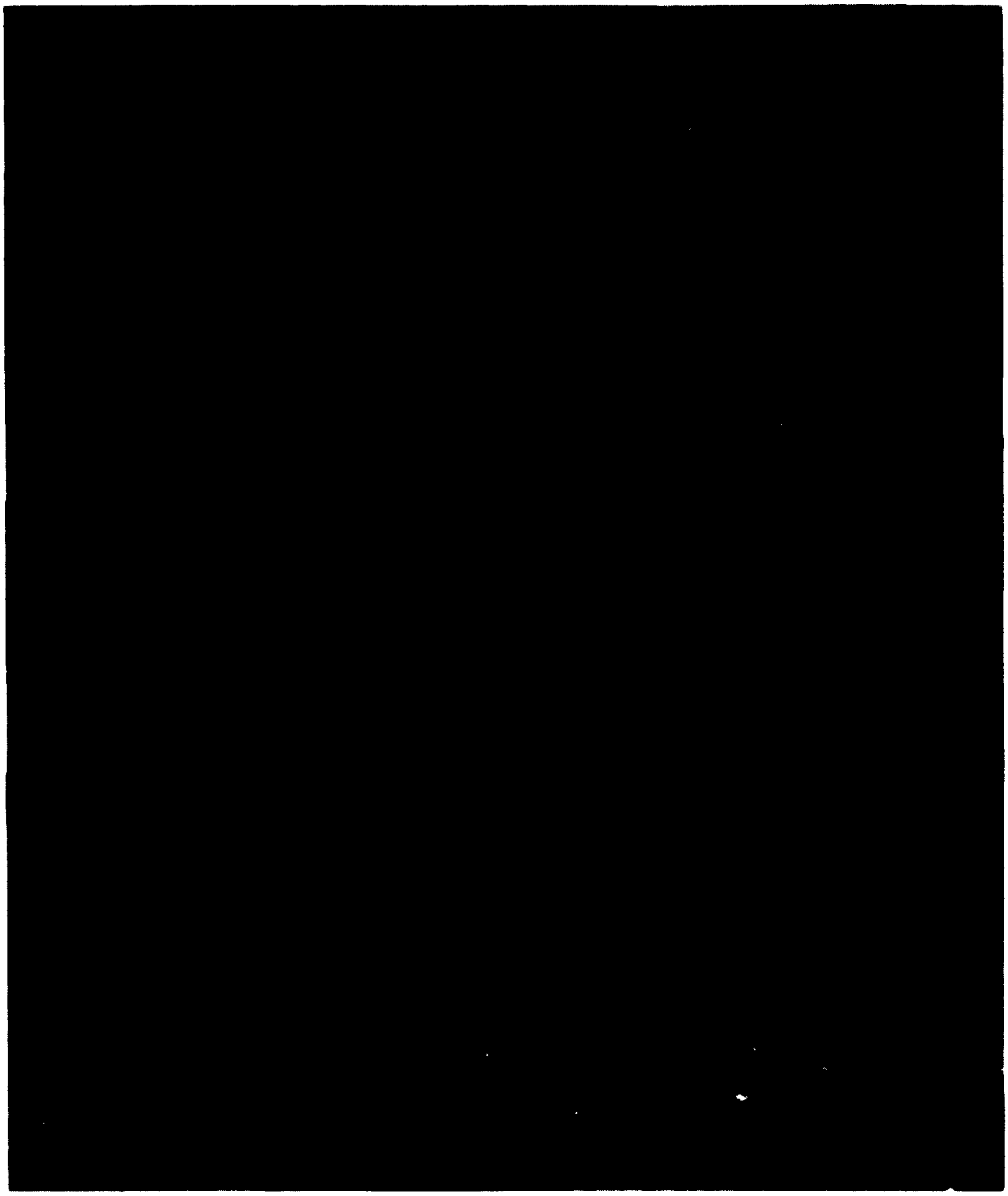
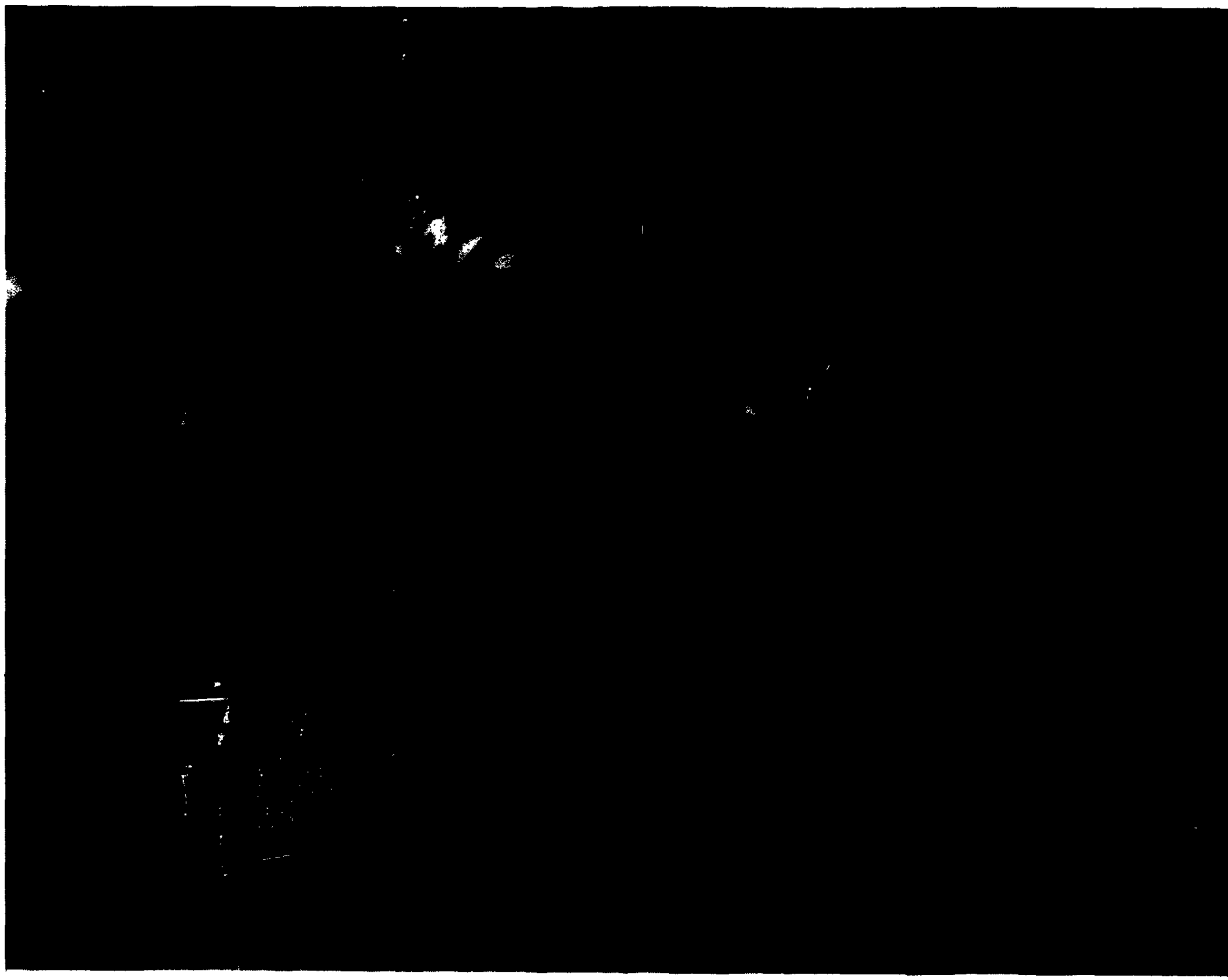

REhfe vs D.C. READOUT
(Taken on the circuit of Fig. 5)
X Portion of Figure 3
Loranger Socket in Fig. 16
(long leaded devices)
Jettron Socket in Fig. 14 & 15
(long leaded devices)
70
60
50
40
30
20
10
Rehfe - ohms

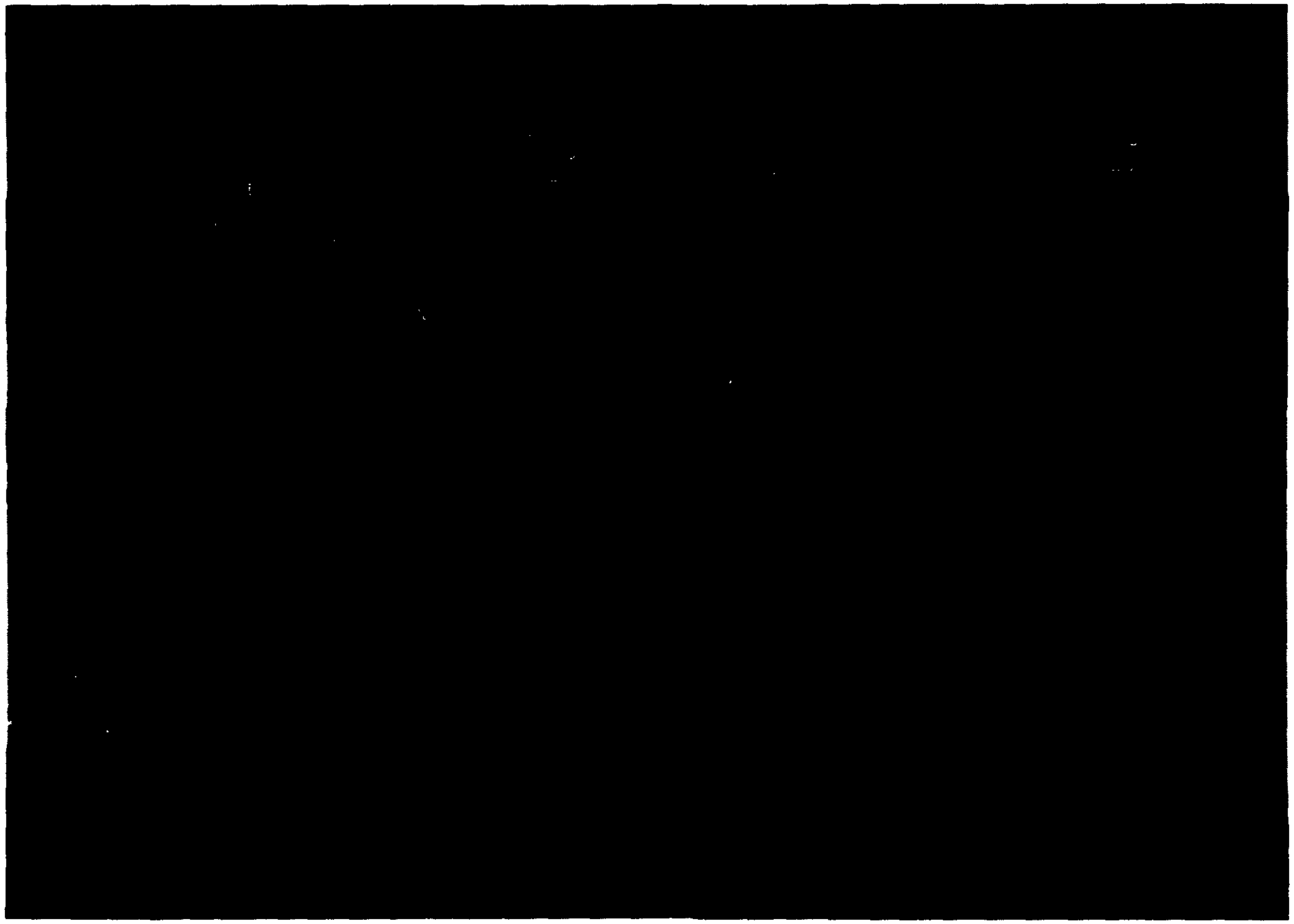
FIGURE 5.1-4



SIMPLIFIED VERSION OF REh_{ie} EQUIPMENT AS USED FOR EXPERIMENTS WITH MECHANIZABLE SOCKETS
FIGURE 5.1-5

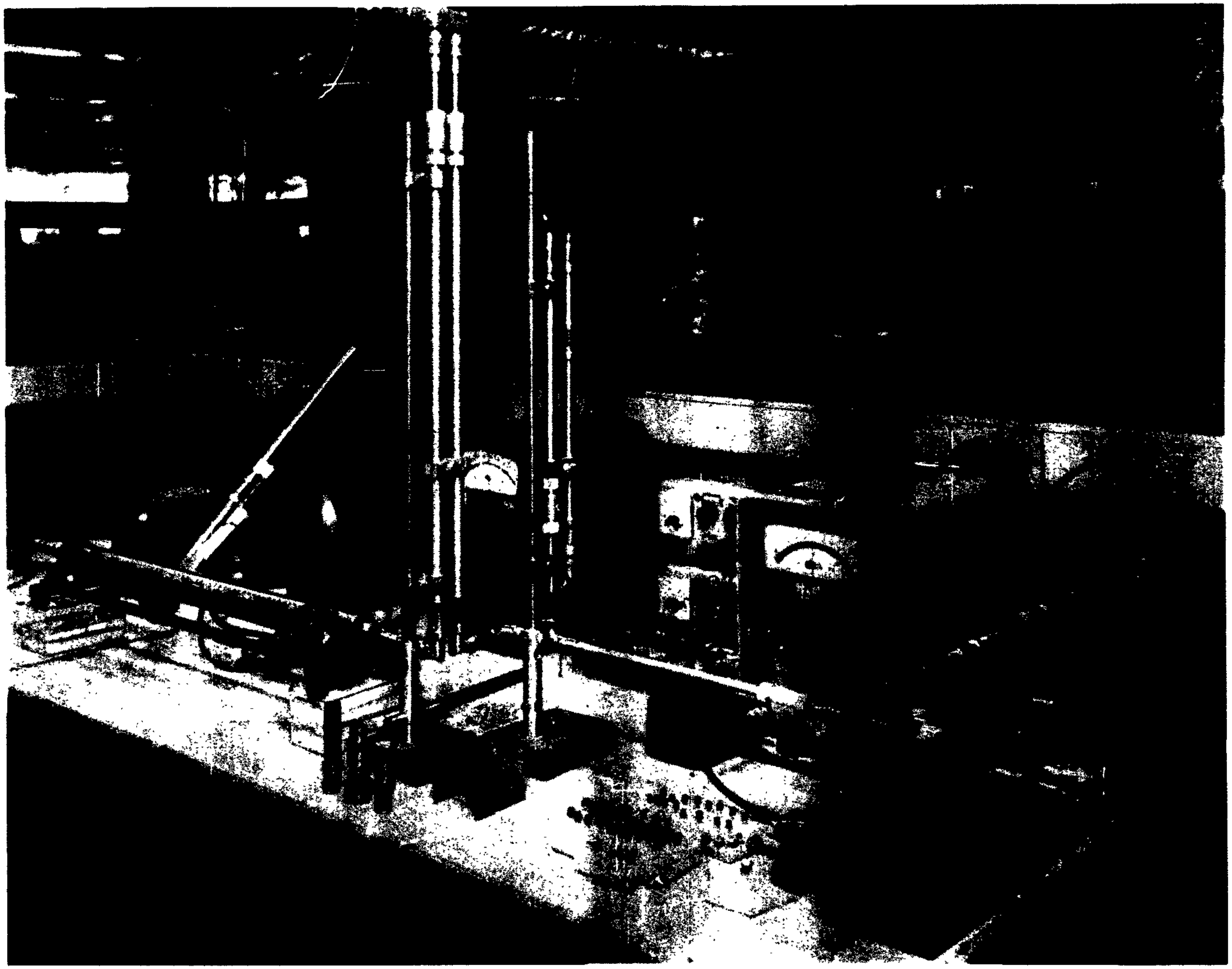


CLOSEUP OF MECHANIZABLE SOCKET USED
ON EQUIPMENT OF FIGURE 5.1-5
FIGURE 5.1-6

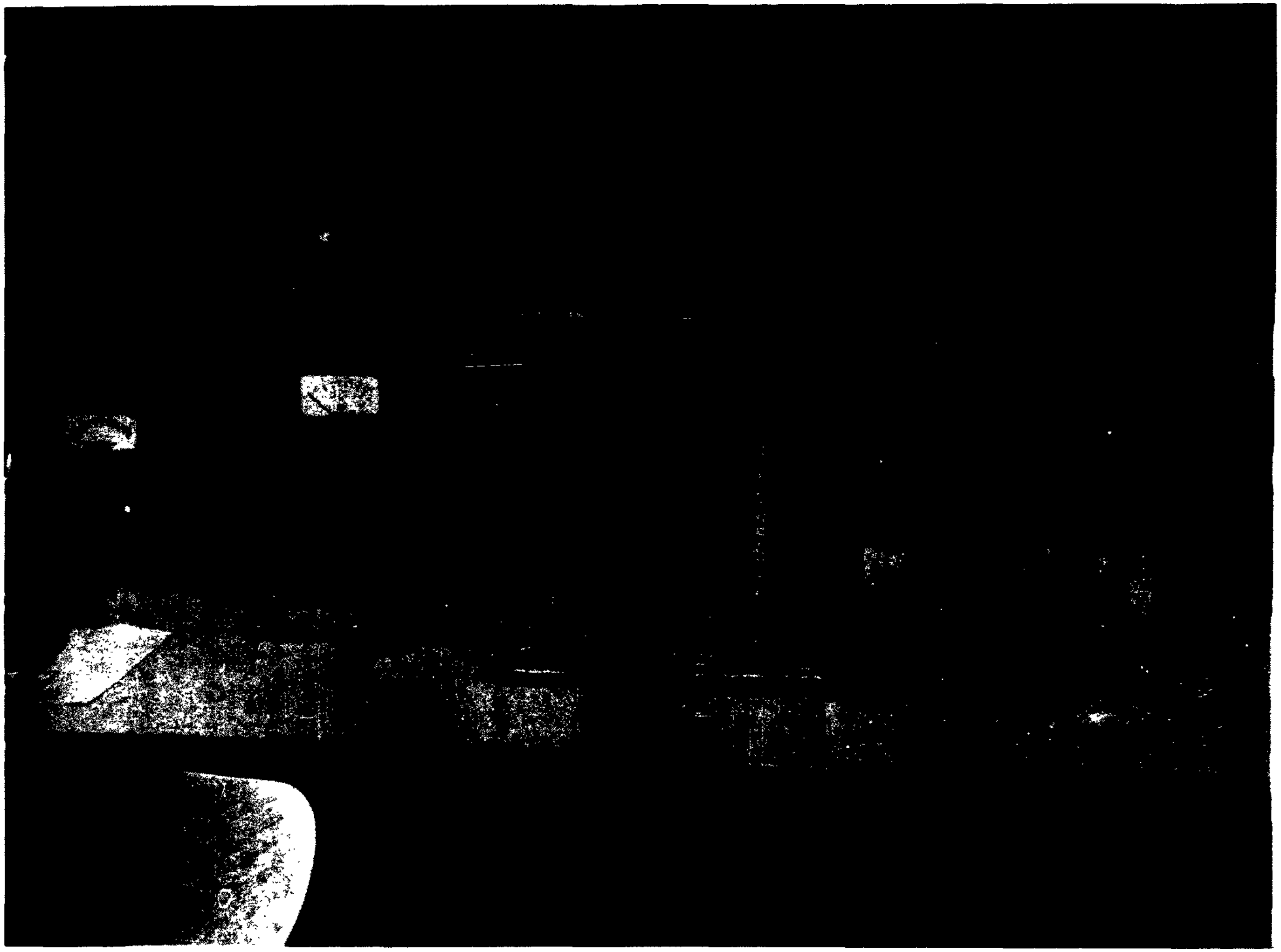


GENERAL RADIO IMMITANCE BRIDGE SET UP FOR REh_{ie} MEASUREMENTS
FIGURE 5.1-7

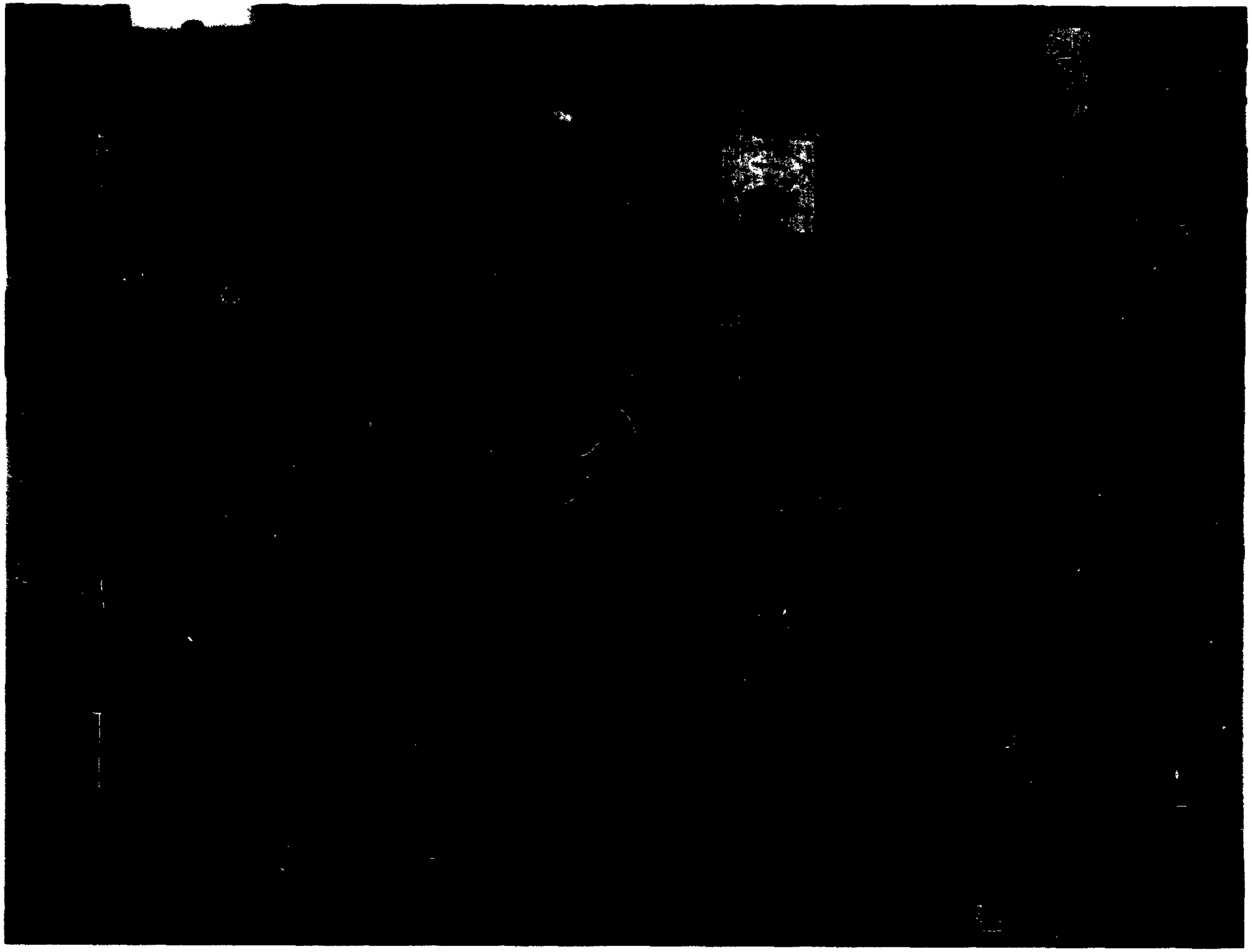
DEVELOPMENTAL REh_{1e} APPARATUS SET UP FOR GO NO-GO PRODUCTION TESTING
FIGURE 5.1-8



SLOTTED LINE SET UP TO MEASURE PHASE SHIFT OF
STANDING WAVE IN REh_{ie} DEVELOPMENTAL TEST CIRCUIT
FIGURE 5.1-9



OVERALL VIEW OF 100MC h_{fe} APPARATUS
FIGURE 5.1-10



CLOSEUP VIEW OF 100MC h_{fe} TEST CIRCUIT
FIGURE 5.1-11

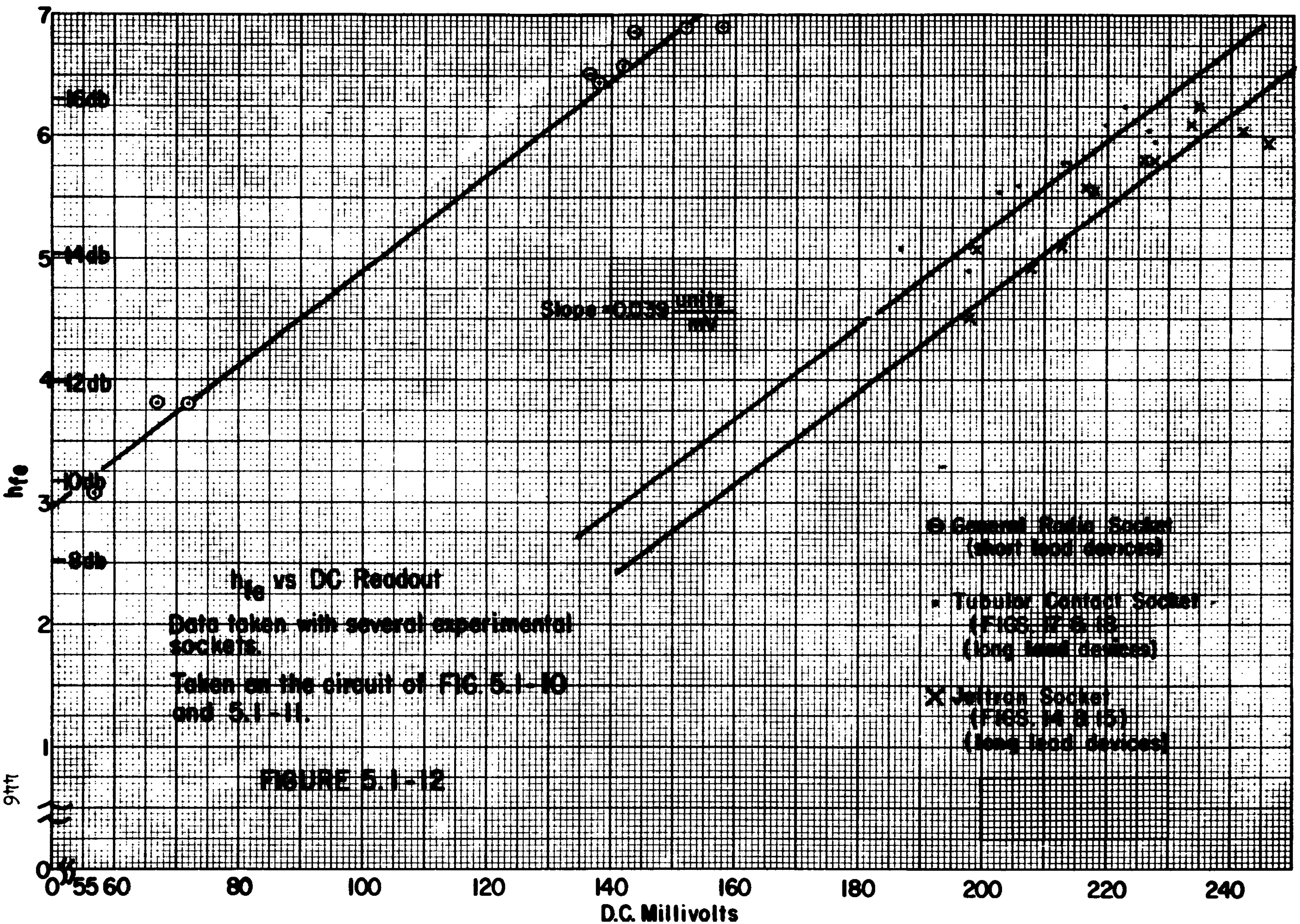
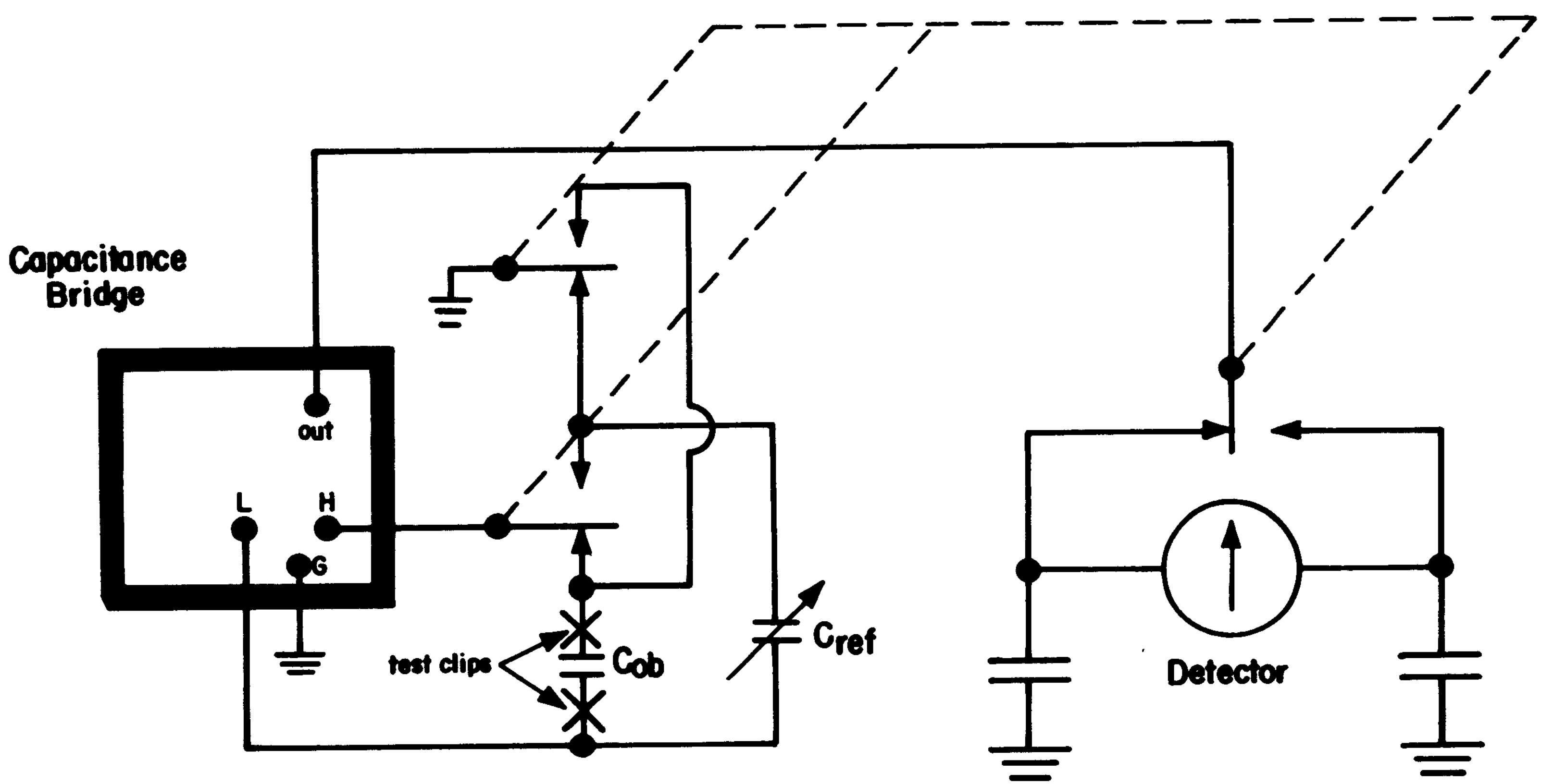
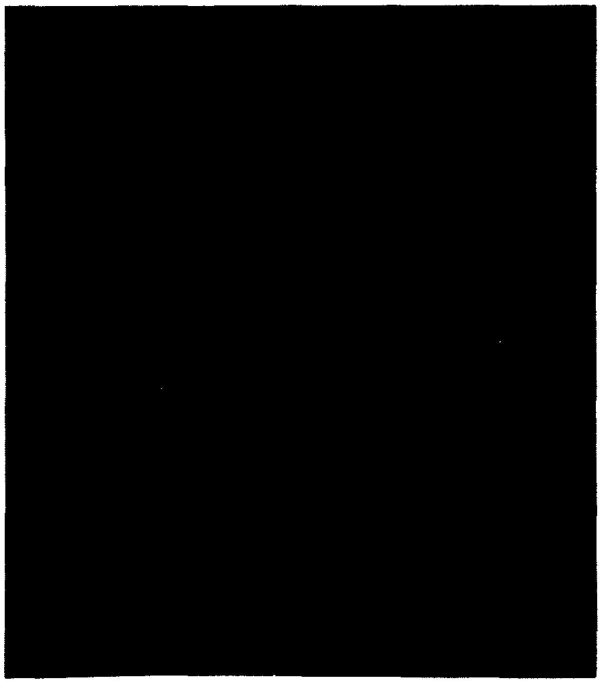

hfe vs DC Readout
Data taken with several experimental sockets.
Taken on the circuit of FIG. 5.1-10 and 5.1-11.
Slope = 0.039 units/mV
⊙ General Radio Socket (short lead devices)
▪ Tubular Contact Socket (FIGS. 17 & 18) (long lead devices)
X Jettron Socket (FIGS. 14 & 15) (long lead devices)
16db
14db
12db
10db
8db
hfe
D.C. Millivolts
0
1
2
3
4
5
6
7
0
55
60
80
100
120
140
160
180
200
220
240

FIGURE 5.1-12

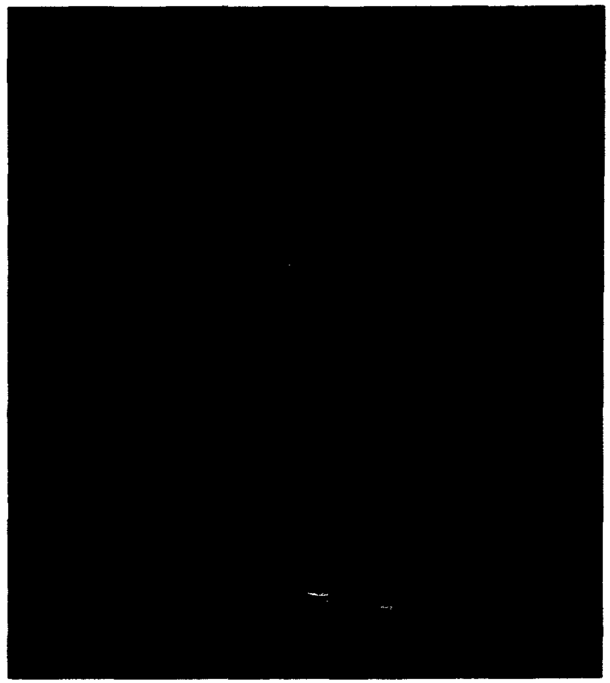


Basic Circuit of C_{ob} Test Set

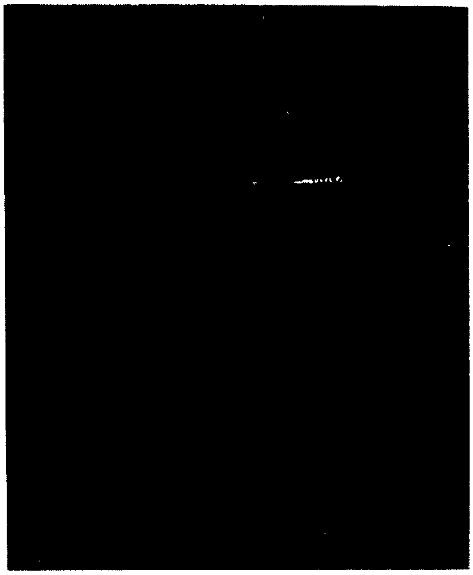
FIGURE 5. 1-13

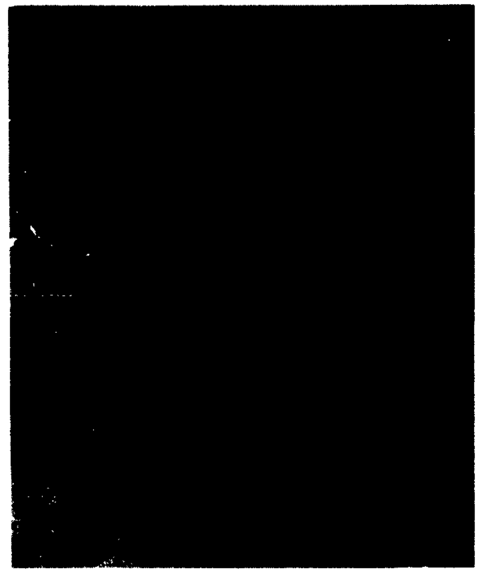


JETTRON SOCKET WITH LEAD SPACER-POSITIONER SHOWN
IN CONTACT WITH LEAF SPRING CONTACTS
FIGURE 5.1-14



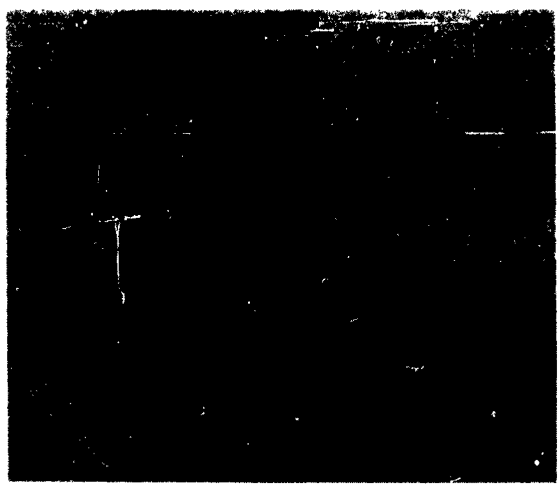
JETTRON SOCKET OF FIGURE 5.1-14 REMOVED FROM CONTACT ASSEMBLY
FIGURE 5.1-15



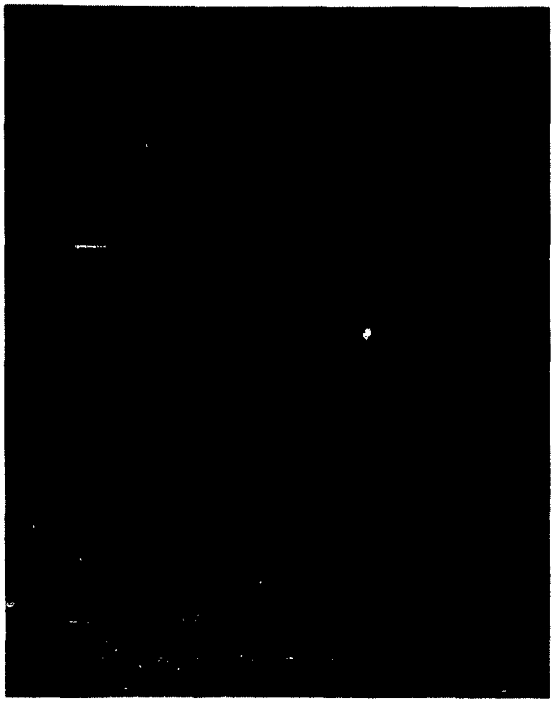


LORANGER 2293A SOCKET WITH LEAD SPACER-POSITIONER ATTACHED
FIGURE 5.1-16

EXPERIMENTAL TUBULAR CONTACT SOCKET WITH EXTERNAL EMITTER AND COLLECTOR GROUND PLANE ATTACHMENT.
FIGURE 5.1-17



TUBULAR CONTACT SOCKET DISASSEMBLED TO SHOW GROUNDING STRUCTURE AND COLLECTOR SHORTING CAPACITOR
FIGURE 5.1-18



A MECHANIZABLE SOCKET WHICH GAVE GOOD RESULTS
FIGURE 5.1-19

SOCKET OF FIGURE 5.1-19 DISASSEMBLED TO SHOW CONTACT DETAILS
FIGURE 5.1-20

SECTION 5.2

THERMOCOMPRESSION BONDING

OF

SMALL DIAMETER GOLD WIRE

M. K. Avedissian

THERMOCOMPRESSION BONDING OF SMALL DIAMETER GOLD WIRE

I General

Wire bonding or lead attachment to the internal parts of transistors is one of the last assembly operations on the functional parts of the transistor itself. It is therefore desirable to know more about the mechanism of thermocompression wire bonding and the factors influencing the reliability and repeatability of this operation for the purpose of increasing the overall rate and yield of transistor manufacturing.

The purpose of this work was to obtain basic information and help establish requirements for reliable thermocompression wire bonding.

II The Process of Bonding

Thermocompression bonding is closely related to bonding by adhesion. Metal to metal adhesion can be established at room temperature. Addition of heat and pressure helps to penetrate oxide and contaminating films. Frequently oxide films are harder than the underlying material, but usually they are easily pierced by another solid: It is similar to the ease of piercing a film of ice when there is soft mud underneath.

For strong bonds, the surfaces must be clean. With clean surfaces, a plastic deformation is produced which causes effective welding (pressure welding). Any contamination will reduce the strength of the bond. Especially detrimental is the presence of any lubricants. If a heavy load is applied so that some deformation of the underlying surface occurs, some adhesion will result even in the presence of lubricants; however, the strength will be poor. A film of lubricant reduces the metallic interaction to a very low value. Normal and tangential stresses lead to growth of the junction area only if the surfaces are so clean that wherever they come in contact they form a strong metallic junction. For this to occur, the surfaces must be thoroughly denuded of oxide or other contaminating films. Alternatively, if the metals are very soft, the surface films are easily ruptured and junction growth can occur.

A number of experiments were performed in an attempt to isolate major factors preventing reliable thermocompression wire bonding operation. As expected, contamination of the surfaces to be bonded proved to be a major cause. Another factor, without doubt, is the influence of oxide layers; however, these are difficult to determine and avoid.

Because of the small size of the parts to be wire bonded during transistor manufacture, it is not possible to see or measure contamination. The most practical measurement appears to be the bondability of the processed part itself. In the experiments conducted, units were selected which could not be bonded at all - there was no adhesion possible between the evaporated stripes (either gold or aluminum) and the gold wire. Units and wire were taken out of the machine, thoroughly cleaned and put back into the machine. Now the same units bonded easily and the pull tests indicated good strength. It is interesting to note that some units which prior to the cleaning operation did not show any tendency to bond exhibited maximum strength of the bonds which was indicated by the wire breaking before the bond separated.

If temperature, pressure, and tooling of the bonding operation are correct and not changed, a difference in the visual appearance of good and poor bonds can be observed. The difference is in the degree of mashout or deformation of the wire at the bond. If the surfaces are clean and the bondability good, the mashout at the bond is relatively small. If cleanliness and bonding conditions are fair, a bond can be made;

however, a relatively wide mashout will result. This observation can be explained in the following manner: During deformation of the gold wire, the area of contact between wire and stripe is gradually increasing. With good bonding conditions present, the junction area grows and until a state of mechanical equilibrium is attained. With poor bonding conditions present, however, the gold wire has the tendency to slide on the surface instead of forming a continuous junction.

Two clean surfaces pressed against each other will bond; however, unless at least one surface is plastic enough, the recovery of the elastic deformation at pressure removal will break the bond. Therefore, at least one of the materials to be bonded must be plastic enough to prevent destruction of the bond. The gold wire used in transistor manufacture, is subject to a certain degree of annealing when brought in contact with the hot area to which the bond is to be made. For this reason, even hard gold wire (less than 1 percent elongation) can be used for thermocompression Wire Bonding as it acts as the plastic material. Experiments indicated, however, that softer wire, minimum 4 percent elongation, should be used. This experiment was made with .0005-inch-diameter gold wire; however, it is believed the result is valid for other small diameters as well.

The thickness of the stripes on the semiconductor wafer also has an influence on the bondability of the units. It has been experienced that cleanliness requirement becomes more critical with thin stripes. Thicker stripes tolerate a certain amount of contamination. It is difficult to define the terms "thick" and "thin": It appears that stripe layers of less than 2,000 Å are more critical to bond than stripe layers of more than 5,000 Å. However, the tests made also indicate this difference can be reduced to a high degree and perhaps even eliminated by greater emphasis on absolute cleanliness.

III Conclusion

The process of thermocompression Wire Bonding is a reliable and repeatable one if proper working conditions are provided. The tests made indicate the importance of cleanliness of the surfaces to be bonded. Several groups of units which could not be bonded were selected; after thorough cleaning of wafer-bonded headers and wire, marked improvement was always noted. Other factors are also involved which are associated with the material preparation prior to wire bonding. More work in this direction is desirable in order to optimize the Wire Bonding operation.

IV Recommendation for Phase 2

Thermocompression bonding is only one method of making bonds by adhesion or pressure welding. Other methods are known, such as, ultrasonic bonding and welding; however, their reliability and repeatability with small diameter wires are not proven. Development work in this area could open new avenues toward a better and simpler Wire Bonding operation.

V Bibliography

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SECTION 5.3

CENTRIFUGE TESTING

OF

INTERNAL LEAD CONNECTIONS OF TRANSISTORS

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J. A. Clancy

CENTRIFUGE TESTING OF INTERNAL LEAD CONNECTIONS OF TRANSISTORS

I General

The objective of this report is to establish a criterion for determining the reactive forces at the bonds of the internal connections made with gold wire in transistors when exposed to 20,000 G's acceleration. Employing the existing "Pull Tester" it is possible to simulate these reactive forces, thus providing a convenient means to check and control the process of Wire Bonding or internal lead attachment.

The wire attached to the stripe and post of a transistor has a certain slack. At low G-levels, this wire is elastic. At high G-levels, however, plastic zones are developed in the wire. The shape attained by the wire beyond this G-level is assumed to be a catenary. Photographs made (Figures 5.3-11, 12, 13, and 14) verify that at high G-levels the wire assumes a shape similar to a catenary and that plastic set occurs. Therefore, the above-mentioned assumption is permissible. It serves to establish the length and thereby the weight of the wire and also the directions of the reactive forces. While it is agreed that an error is introduced by making this assumption, the results obtained become more conservative. Therefore, they are useful for all practical purposes.

II Objectives

The problem to be analyzed can be divided into the following three sub-divisions:

1. Physical Properties of the Gold Wire

   How does the wire physically react to the application of high G-loads?

2. Forces

What are the maximum resultant forces at the bonds? How do the dimensions of the transistor lead structure affect these forces?

3. Correlation

After calculating the location and magnitude of the forces, establish a significant means of correlating the uniformly distributed centrifugal load to the concentrated load of a "pull-test".

In the ensuing development of theory and formulae to fulfill the above objectives, possible deflections of the lead structures have been neglected. As shown in Part V, of this study, the choice of the axis of centrifuging allows such an assumption; for other possible orientations in the centrifuge, the deflections may still be excluded because they would not have a significant contribution to the failure of the wire or wire bond.

III Description of Structure

While the 2N559 transistor is the device for which most of the numerical solutions were obtained, the theory applies to all similar packages and the formulae can be adjusted to accommodate minor variations.

Figure 5.3-3 illustrates a typical 2N559 bonded transistor, while Figure 5.3-4 shows more clearly the elements of greatest importance, namely the stripes, wire, and lead structures. In the calculations, various dimensions F and B are employed as well as both .001-inch-diameter and .0005-inch-diameter wire. Table I, on the next page, lists the symbols and design information which are used in this report.

TABLE I

SYMBOLS USED IN THIS STUDY

UNIT	SYMBOL	RANGE AND/OR UNITS
Length	F:	.035 - .070 in.
Height	B:	.015 - .035 in.
Diameter:	d:	.0005 - .001 in.
Density	ρ:	Au - 315.671 gm/in^3
Gravitational Constant	g:	g = 32.2 ft/sec^2
Centrifugal Level	G:	Gravitational Intensity expressed in multiple of the constant g.
Weight	W:	gm
Weight per Unit Length	w, q:	gm/in
Horizontal Force	H:	gm
Area	A:	in^2
Stress	σ:	gm/in^2
Moment of Inertia	I:	in^4
Young's Modulus	E:	gm/in^2

IV Theoretical Analysis

1. Physical Properties of Gold Wire under Centrifugal Loading

Figure 5.3-1 and Figure 5.3-2 represent recordings of an Instron tester made with .0005-inch-diameter and .001-inch-diameter gold wire. Figure 5.3-1 indicates the elastic limit of the .0005-inch-diameter gold wire to be 1.1 grams with total failure occurring at 1.5 grams after an elongation of 5 percent. Figure 5.3-2 shows the results of subjecting a 2-inch length of .0005-inch-diameter gold wire to increasing loads, maintaining these loads for short periods of time to notice any relaxation of the material. Under a pure tensile load of 0.1 gram there is no appreciable relaxation, while at 0.8 gram, relaxation becomes evident. However, after removal of the 0.8-gram load, a permanent elongation was not measurable; the wire assumed almost exactly its original length.

In order to analyze the forces developed at the bonds at 20,000 g's, it is necessary first to establish the curve which is attained by the wire. At low G-levels the wire is elastic and will be exposed to bending. If the yield limit of the wire material is exceeded appreciably (bending), the wire will assume a shape similar to a catenary.

The elastic limit of the .0005-inch-diameter gold wire was found to be 1.1 grams. Therefore, the stress at the upper limit of the elastic range can be calculated:

$$\sigma_y = T \Big/ \frac{\pi d^2}{4} \qquad (1)$$

where

d = .0005 inch

T = 1.1 grams (axial load)

therefore,

$$\sigma_y = \frac{1.1 \times 4}{\pi \times (.0005)^2}$$

$$\sigma_y = 560 \times 10^4 \text{ gm/in}^2$$

This is the tensile stress at which the fibers of the wire will yield. When the bending moment producing this stress at the extreme fibers of the wire cross-section is exceeded, the stress can not rise; however, the strain can and will. Therefore, with increase of the bending moment, more fibers in the cross-section of the wire will be exposed to the yield stress. Eventually the entire cross-section will be exposed to this stress.

The location of the zones exposed to highest bending stress are at the post and stripe bonds. These are the sections of the wire which will yield first. As the G-level is increased, the length of the zones of the wire exposed to bending yield stress will increase. For all practical purposes, it can be assumed the shape of the wire to approach a catenary.

The moment M_{el} which will produce a yield stress of the extreme fibers only is

$$M_{el} = \sigma_y \frac{\pi d^3}{32}$$

With this moment, the extreme fiber stress just equals the yield stress, and the bending moment carried is the largest possible one within the elastic limit. If the moment is increased beyond that, the outer fibers would develop stresses higher than the yield stress if this is possible. But Hooke's law no longer holds and the stress just remains constant while the strain continues to grow. The outer fibers come into the plastic stage, and as the bending moment grows, more and more fibers become plastic until finally the whole cross-section is plastic. The moment creating this condition, which stresses the innermost fibers to the yield point, is M_{pl}.

For circular cross-sections[1]

$$\frac{M_{pl}}{M_{el}} = 1.7$$

The acceleration which will produce the moment M_{pl} can be calculated. To simplify this calculation, assume a straight wire bond as existing between the post and the stripe (see Figure 5.3-5).

In Figure 5.3-5 the wire is shown as a beam of length L rigidly supported at both ends and with uniformly distributed load of q weight per unit length acting on it. The reactions V_1 and V_2 can be expressed as

$$V_1 = V_2 = \frac{q\,L}{2} . \tag{2}$$

The general expression for the elastic line is

$$M(X) = EI\,\frac{d^2Y}{dX^2} \tag{3}$$

(This equation is accurate for small deflections.)

where M(X) is the bending moment expressed as a function of X.

The moment M_o about O is

$$M(X) = M_o - V_1 \cos\alpha\, X + \frac{q \cos\alpha\, X^2}{2} ; \tag{4}$$

therefore,

$$EI\,\frac{d^2Y}{dX^2} = M_o - V_1 \cos\alpha\, X + \frac{q \cos\alpha\, X^2}{2} . \tag{5}$$

Integrating once:

$$EI\,\frac{dY}{dX} = M_o X - V_1\,\frac{\cos\alpha\, X^2}{2} + \frac{q \cos\alpha\, X^3}{6} + C \tag{6}$$

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(1) Timoshenko - "Strength of Materials", Vol. II, Third Ed., P. 353

The left-hand side of Equation 6 equals EI tan α at $X = 0$ and $X = L$. Therefore, substituting $X = 0$ and $\frac{dY}{dX} = \tan\alpha$ the value of the constant C is found to be:

$$C = EI \tan\alpha \tag{7}$$

Solving Equation 6 for $X = L$ results in the following:

$$EI \tan\alpha = M_0 L - \frac{V_1 \cos\alpha\, L^2}{2} + \frac{q \cos\alpha\, L^3}{6} + EI \tan\alpha \tag{8}$$

or

$$M_o L - \frac{V_1 \cos\alpha\, L^2}{2} + \frac{q \cos\alpha\, L^3}{6} = 0.$$

Therefore, since

$$V_2 = V_1 = \frac{qL}{2}$$

$$M_o L - \frac{q \cos\alpha\, L^3}{4} + \frac{q \cos\alpha\, L^3}{6} = 0. \tag{9}$$

Thus

$$M_o = \frac{q \cos\alpha\, L^2}{12}. \tag{10}$$

Equation 4 can now be rewritten and expressed in terms of the one variable X:

$$M(X) = \frac{q \cos\alpha\, L^2}{12} - V_1 \cos\alpha\, X + \frac{q \cos\alpha\, X^2}{2} \tag{11}$$

The maximum M(X) occurs at $X = 0$ and $X = L$ and is equal to

$$M(X)_{max} = \frac{q \cos\alpha\, L^2}{12}. \tag{12}$$

To calculate what G-level will result in yielding of the bonded wire, σ_y of Equation 1 will be equated to the product of the maximum bending moment (M_{pl}), which is a function of q and the section modules S. It will be shown later that the contributions of shearing and axial forces are negligible; therefore, they are not taken into consideration.

$$M_{pl} = 1.7\ M_{el} = 1.7\ \frac{\pi d^3}{32}\ \sigma_{yel}$$

$$M_{pl} = \frac{q \cos\alpha\ L^2}{12}$$

$$q = \frac{M_{pl} \times 12}{\cos\alpha\ L^2} = \frac{1.7 \times \pi \times d^3 \times \sigma_{yel} \times 12}{32 \times \cos\alpha \times L^2} \tag{13}$$

also

$$q = G\rho A = G\rho\ \frac{\pi d^2}{4} \tag{14}$$

Equating Equations 13 and 14 gives

$$\frac{1.7 \times 12 \times \pi \times d^3 \times \sigma_{yel}}{32 \times \cos\alpha \times L^2} = G\rho \frac{\pi d^2}{4}$$

$$G = \frac{1.7 \times 12 \times \sigma_{yel}}{8 \times \rho} \times \frac{d}{\cos\alpha\ L^2}$$

Substituting the material constants results

$$G = \frac{1.7 \times 12 \times 560 \times 10^4}{8 \times 315.67}\quad \frac{d}{\cos\alpha\ L^2}$$

$$G = 4.5 \times 10^4\ \frac{d}{\cos\alpha \times L^2}$$

It is more convenient to express G as a function of the horizontal distance F between stripe and post (see Figure 5.3-5).

$$F = L \cos \alpha$$

$$G = 4.5 \times 10^4 \frac{d \cos \alpha}{F^2} \quad . \tag{15}$$

For nominal dimensions $\alpha = 43^\circ$ and $F = .035$ inch

$$G = 13400 \text{ g's}.$$

At this G-level, from Equation 14 follows

$$q = 0.83 \frac{gm}{in} \cdot$$

From Equation 2

$$V_1 = V_2 = \frac{0.83 \times 0.035}{2 \times \cos \alpha} = 0.0198 \text{ gm}.$$

Axial forces

$$V_A = 0.0198 \times \sin 43^\circ = \pm 0.0135 \text{ gm} ;$$

shearing force

$$V_S = 0.0198 \cos 43^\circ = 0.0145 \text{ gm} ;$$

stress due to axial forces

$$\sigma_A = \pm 6.9 \times 10^4 \text{ gm/in}^2 ;$$

stress due to shearing force

$$\sigma_S = 7.4 \times 10^4 \text{ gm/in}^2.$$

These stresses can be neglected in comparison with

$$\sigma_y = 560 \times 10^4 \text{ gm/in}^2.$$

Beyond 13,400 g's, sections of the wire are capable of plastic deformation in bending; they are no longer capable of transferring bending moments. With increase of the G-level, the length of these plastic zones will increase, and the wire will approach the shape of a catenary. For this analysis the shape of the wire is assumed to be a catenary. Although the plastic zones will yield in bending, the system will again stabilize itself since these same sections of the wire are capable of carrying tensile loads. The tensile yield strength of the 0.0005-inch-diameter gold wire was found to be 1.1 grams. As will be shown by the ensuing calculations, a G-level of 20,000 g's does not approach the required load in tension of 1.1 grams to cause a tensile yielding of the wire.

There are three possible approaches to this problem:

1. The catenary approaches the post with a negative slope.
2. The catenary approaches the post with a positive slope.
3. The catenary approaches the post with zero slope.

Along a catenary, the horizontal component H of the force is a constant. The worst condition for the reaction at the stripe bond is when the catenary has a horizontal tangent at the post. In this case the reaction at the stripe bond will involve not only the constant horizontal component H, but also the vertical component V_R which is equal to the entire weight of the wire at the particular G-level. Therefore, this condition has been adopted for the analysis (see Figure 5.3-6).

<u>The Catenary</u>[2]

$$Y = \frac{H}{w} \cosh \frac{wX}{H} + C \tag{16}$$

(2) Timoshenko and Young - Engineering Mechanics: Statics, Fourth Edition, P. 165

$$\frac{H}{w} = a \text{ (parameter of the catenary)}$$

$$Y = a \cosh\left[\frac{X}{a}\right] + C \tag{17}$$

For $X = 0$

$$Y = a + C$$

By choosing $C = 0$, the lowest point of the catenary is

$$Y = a \quad \text{for } X = 0 \quad \text{(see Figure 5.3-7)}$$

therefore,

$$Y = a \cosh\left[\frac{X}{a}\right] \tag{18}$$

The increment length of the catenary as a function of coordinate X and Y is

$$ds = \sqrt{1 + \left[\frac{dY}{dX}\right]^2}\; dX \tag{19}$$

and

$$s = \int_0^F \sqrt{1 + \left[\frac{dY}{dX}\right]^2}\; dX. \tag{20}$$

Differentiating Equation 18

$$\frac{dY}{dX} = \sinh\left[\frac{X}{a}\right]$$

Squaring and substituting in Equation 20

$$s = \int_0^F \cosh\left[\frac{X}{a}\right] dX$$

or

$$s = a \sinh\left[\frac{F}{a}\right] \tag{21}$$

We can adjust Equation 18 to eliminate the hyperbolic dependency and make the relationship easier to work with. To do this we use the following two McLaurin series expansions[3]:

$$e^z = 1 + \frac{z}{1!} + \frac{z^2}{2!} + \frac{z^3}{3!} + \cdots \qquad (22)$$

$$e^{-z} = 1 - \frac{z}{1!} + \frac{z^2}{2!} - \frac{z^3}{3!} + \cdots \qquad (23)$$

Addition of Equation 22 and Equation 23 shows that

$$\cosh z = \frac{e^z + e^{-z}}{2} = 1 + \frac{z^2}{2!} + \frac{z^4}{4!} + \cdots$$

where

$$z = \frac{X}{a}$$

with Equation 18: $Y = a \cosh\left[\frac{X}{a}\right]$

$$Y = a\left[1 + \frac{X^2}{2a^2} + \frac{X^4}{24a^4} + \text{- - -}\right].$$

Using the first two factors only

$$Y \doteq a + \frac{X^2}{2a} . \quad \text{(Footnote 4)} \qquad (24)$$

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(3) I.S. and E.S. Sokolnikoff - Higher Mathematics for Engineers and Scientists. Second Ed., P. 250

(4) The Symbol $\doteq$ denotes "approximately".

Evaluating Equation 24 at $X = F$

$$Y = a + B \quad \text{(See Figure 5.3-7)}$$

$$Y - a = \frac{F^2}{2a} = B$$

$$a = \frac{H}{w} \doteq \frac{F^2}{2B}$$

or

$$H \doteq \frac{F^2 w}{2B} \tag{25}$$

3. <u>Numerical Calculation</u>

It is now possible to solve for the maximum tension in the wire, since from Equation 25 we have an expression for the constant horizontal component, while the vertical component will be the weight of the wire.

The method of approach for the 2N559 transistor and other similar packages is the following: after bonding of these devices, there is a slight initial slack in the gold wire. This fact allows the worst possible condition with the given dimensions B and F, a catenary with a horizontal tangent at the post.

Sample calculations involving the 2N559 transistor employing nominal dimensions and .0005-inch-diameter wire are presented. The remainder of the results concerning this device and other possible devices are found in Figure 5.3-15.

From Equation 25:

$$H = \frac{F^2 w}{2B}$$

Substituting nominal dimensions:

$$H = \frac{(35 \times 10^{-3})^2 \ w}{2 \ (32 \times 10^{-3})} \ gm$$

the value of w is:

$$w = \rho A C = 316 \times \frac{\pi d^2}{4} \times 2 \times 10^4$$

$$w = 1.239 \ gm/in.$$

Therefore,

$$H = 23.8 \times 10^{-3} \ gm$$

To calculate the weight of the wire, it is first necessary to know what length of wire is required to form the prescribed catenary:

From Equation 21:

$$s = a \sinh \left[\frac{F}{a}\right]$$

and $$a = \frac{H}{w}$$

therefore,

$$s = \frac{23.8 \times 10^{-3}}{1.239} \times \sinh \left[\frac{35 \times 10^{-3} \times 1.239}{23.8 \times 10^{-3}}\right]$$

$$s = 58.2 \times 10^{-3} \ in.$$

Thus, the weight of the wire is:

$$W = V_R = (58.2 \times 10^{-3})\ (1.239)\ \text{gm}$$

$$V_R = 72.1 \times 10^{-3}\ \text{gm}$$

therefore,

$$T_R = \sqrt{{V_R}^2 + H^2}$$

$$T_R = 75.9 \times 10^{-3}\ \text{gm}$$

It is also desirable to know the angle θ of the force T_R (Figure 5.3-6). The slope of the catenary is given by the first derivative of Equation 18:

$$\frac{dY}{dX} = \sinh \left[\frac{X}{a}\right]$$

For $X = F$

$$\frac{dY}{dX} = \tan \theta = \sinh \left[\frac{F}{a}\right] =$$

$$\sinh \left[\frac{35 \times 10^{-3} \times 1.24}{23.8 \times 10^{-3}}\right]$$

$$\theta = 72^{\circ}$$

It is obvious, T_R will have a shearing component and a peeling component acting on the bond. The strength of the bond in shearing is determined by the unit shear strength of the bond and by the area of the bond. The peeling force, however, does not act on an area; this force acts essentially on a line only, and this is unfavorable, indeed. It is, therefore, desirable to keep the peeling force low by reducing the angle θ.

Recapitulating: with nominal dimensions of the 2N559 transistor using 0.0005-inch-diameter gold wire for bonding and subjecting the device to a load of 20,000 g's, the maximum reactive force will be 75.9 milligrams, located at the stripe. The angle θ of the reactive force T_R will be 72 degrees.

Results involving different sizes gold wire and various header dimensions are listed in Figure 5.3-15.

The 2N559 transistor is also produced by bonding the gold wire on the side of the post instead of on the top. With this type of bonding the wire forms a fairly straight line, with some slack present. Under these conditions, the wire also assumes a shape similar to a catenary at high G-levels. This catenary has also a horizontal **tangent** at the post (See Figure 5.3-12).

4. <u>Method of Correlating Centrifugal Load to Concentrated Load of Pull-Test</u> (See Figure 5.3-9 and Figure 5.3-10)

The parallelogram of forces is constructed for given dimensions F and B, whereby the length $a + b$ is set to be equal to the length of the catenary s for the particular configuration. The force P is applied at approximately $F/2$. By knowing the tension T_R (Figure 5.3-10) the force P can be found.

While a catenary with horizontal tangent at the post is the worst possible condition for centrifugal loading, Figure 5.3-10 reveals that a case where $a + b < s$ will yield a smaller force P. However, every wire bonded unit has a certain slack in the wire. It is obvious that the length $a + b$ has a definite influence on the force P.

Considering all possible variations inherent to the processes used, (length $a + b$, point of application and direction of force P) the use of some safety factor is recommended for the force P. This safety factor is a very important consideration and its value should be carefully determined. It is suggested that a value of 2.5 be the minimum safety factor used for establishing any pull test requirement.

V <u>Centrifuge Experiments</u>

The following experiments were conducted so as to provide visual verification of the preceding theory and discussion.

Description of Experiments

In all cases the transistors were placed in the centrifuge so that the leads pointed in the direction of the center of rotation (Figure 5.3-8). This is the same orientation that was chosen for all theoretical analysis. It was selected because it results in the exposure of the stripe-bond to the maximum force.

All devices were subjected to a minimum centrifugal load of 100,000 g's for a period of one (1) minute. The 100,000 g-level was selected in order to have greater deformation for visual observation.

Experiment A

Three 2N559 transistors without wafers were bonded as usual except that the wire was fastened to the header itself instead of the stripe. These devices were then subjected to a centrifugal load of 200,000 g's and observed under a microscope. (Figure 5.3-11 is a photograph of one of the tested devices).

Results: No wire failures, no bond failures.

Conclusions: The possibility of tensile yielding of the wire itself can be eliminated from the analysis of properties of the 2N559 devices at a G-level of 20,000. From data on Figure 5.3-15 (B = .032; F = .035) follows the tension at 200,000 g's to be approximately 760 milligrams, which is still below the 1.1 grams required to cause tensile yielding of the wire.

Experiment B

Two devices, one with bonds to the top of the posts, the other with bonds to the sides of the posts, were exposed to 100,000 g's acceleration.

Figure 5.3-13 shows the device with bonds to top of the posts before centrifuging: Figure 5.3-14 shows the same device after centrifuging. The deformation or permanent set of the wire is evident. Note how this "set" exposes the bonds at the stripes to a force which acts nearly perpendicular to the wafer. A "peeling" effect is obvious.

Figure 5.3-12 shows the device with bonds to the sides of the posts after centrifuging. Here also a permanent set is evident. In this case only moderate peeling forces are present at the stripes; the stripe bonds are exposed primarily on sheer.

These experiments and photographs lead to the proposition that for the method of bonding to the top of the posts the vertical distance of separation between the stripe and post bonds should be reduced; this will result in a mechanically stronger device. It is an important fact that with greater height difference between post and stripe bonds the action of the stripe bond becomes more of the "peeling" type. This condition, combined with the larger force acting upon the stripe bond as on the post bond, makes the reduction of height difference between stripes and posts desirable.

VI Conclusion

Figure 5.3-15 provides a conclusive summary of the main objectives of this report. The various dimensions B and F were chosen to show the variation of forces and pull test requirements. The numerical results must be regarded as approximations because of the assumption made at the beginning of this report; however, the error involved can be considered to be well within practical limits.

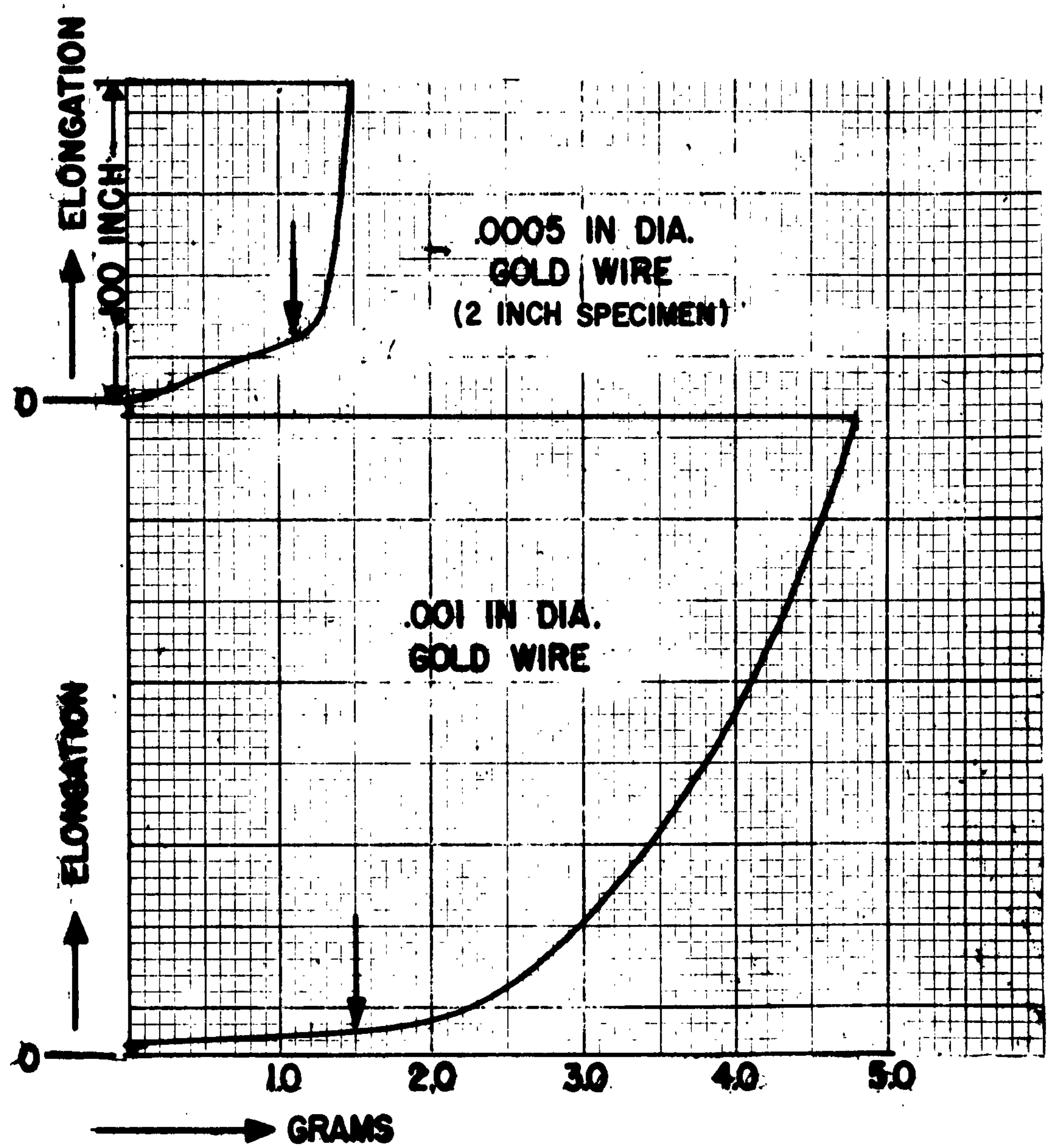


FIGURE 5.3 - 1

RECORDINGS OF TENSILE MEASUREMENTS ON INSTRON TESTER

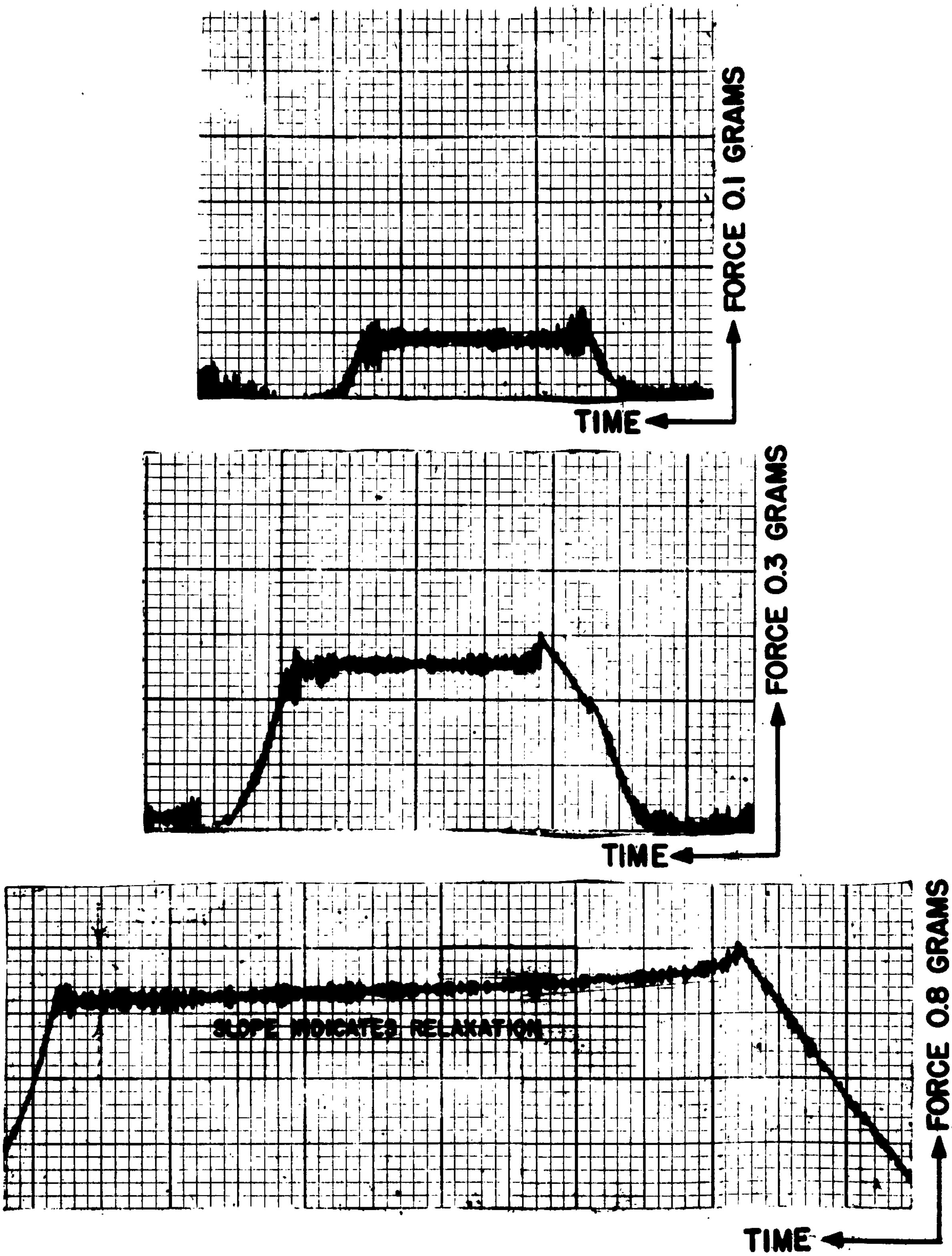


FIGURE 5.3-2
INSTRON RECORDINGS OF RELAXATION OF .0005-INCH-DIAMETER GOLD WIRE

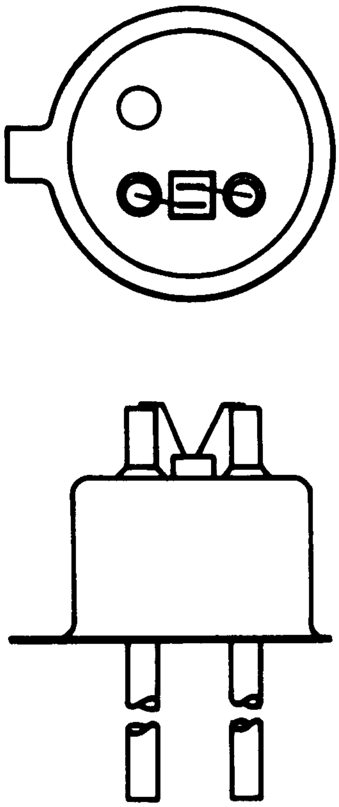


FIGURE 5.3-3

TYPICAL WIRE BONDED
2N559 TRANSISTOR

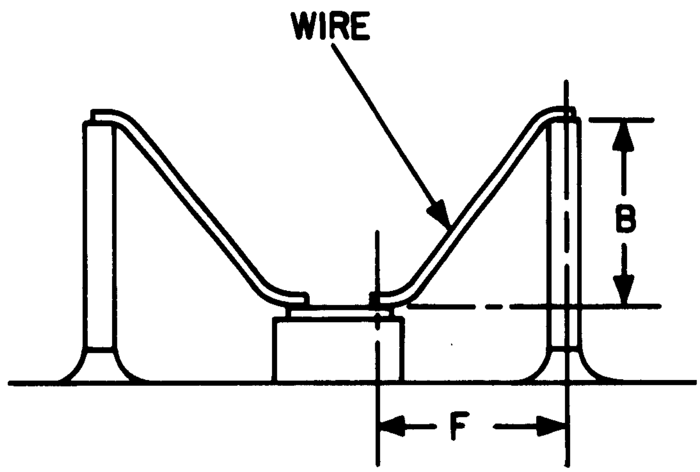


FIGURE 5.3-4

ENLARGEMENT OF WIRE BONDED
STRIPES AND POSTS

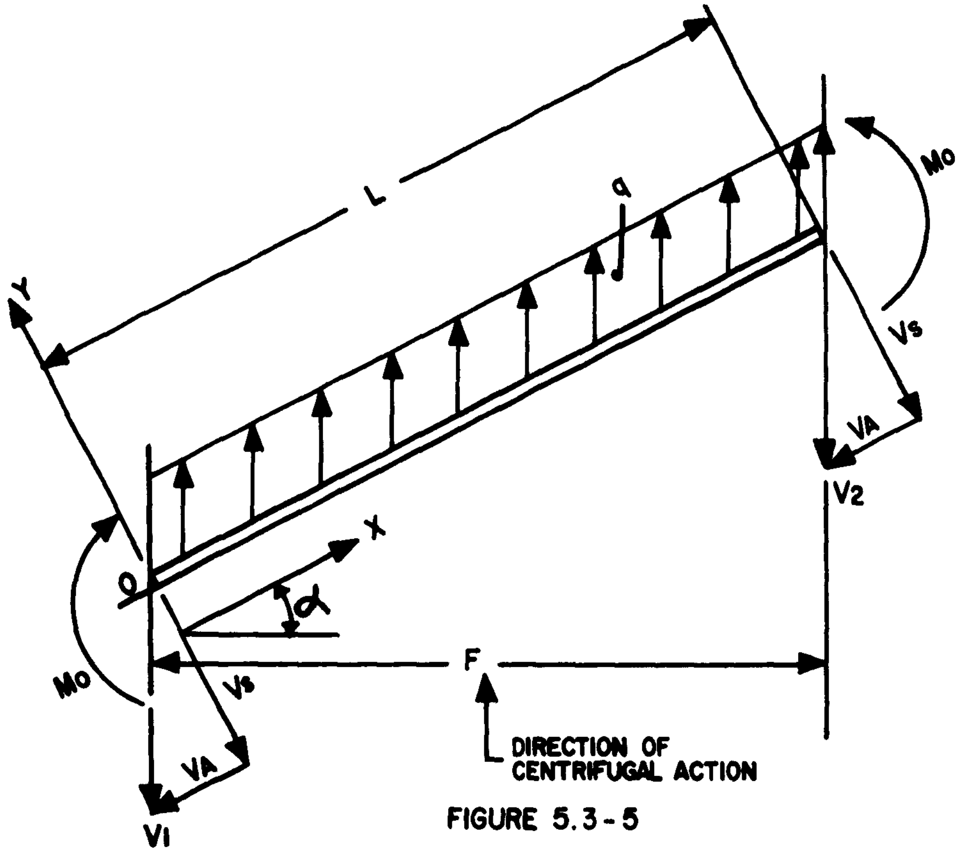


FIGURE 5.3-5

SCHEMATIC REPRESENTATION OF FORCES AND MOMENTS ACTING UPON A STRAIGHT WIRE

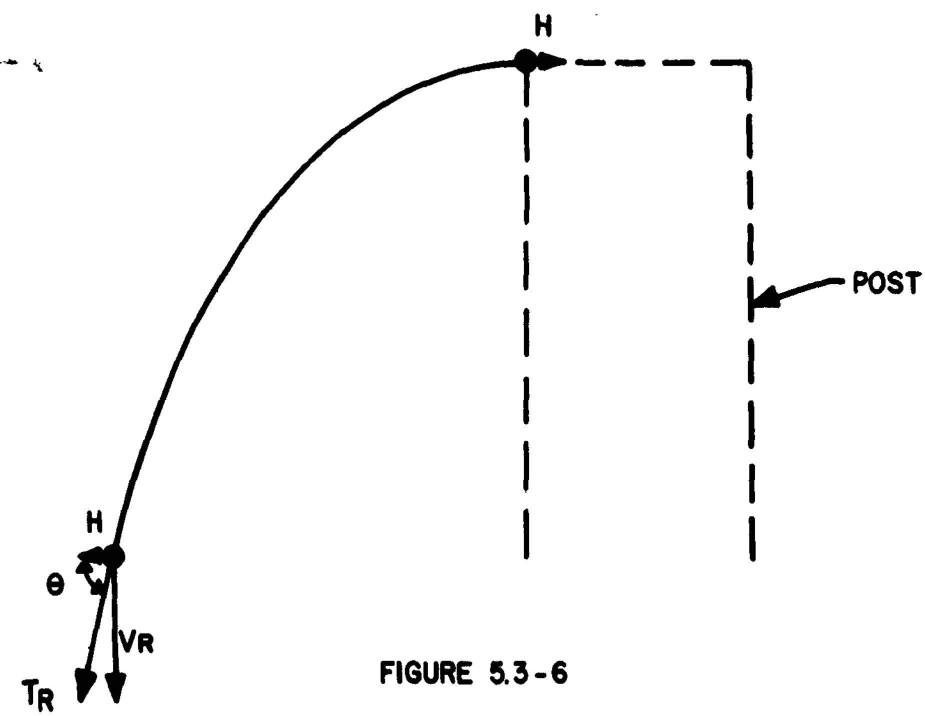


FIGURE 5.3-6

SCHEMATIC REPRESENTATION OF FORCES ACTING UPON CATENARY

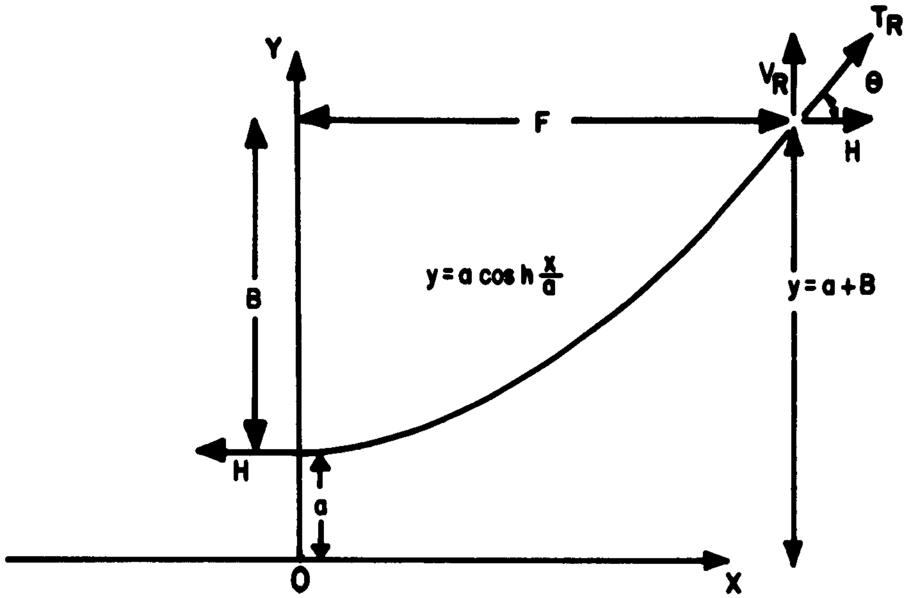


FIGURE 5.3-7

CATENARY IN X-Y CO-ORDINATES

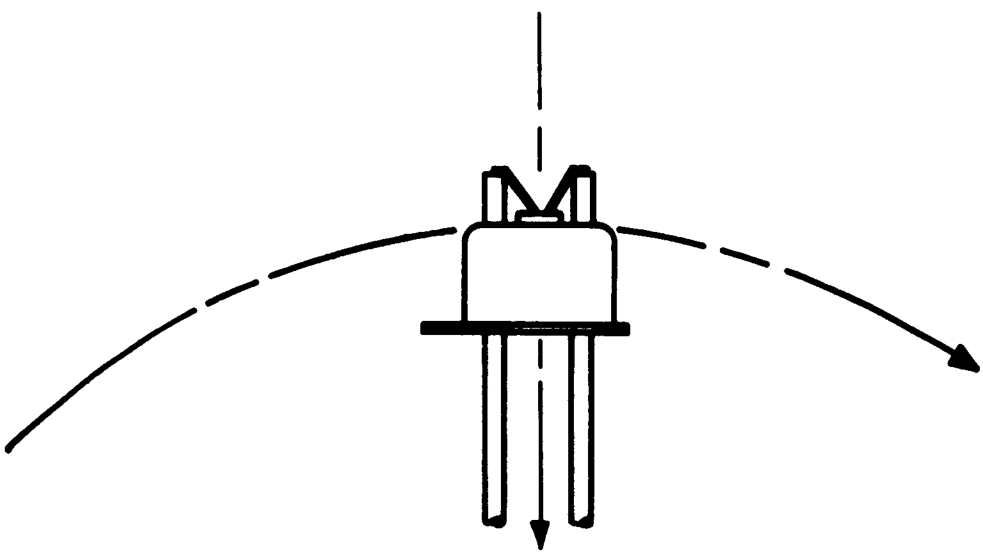


FIGURE 5.3-8

TRANSISTOR ORIENTATION DURING CENTRIFUGING

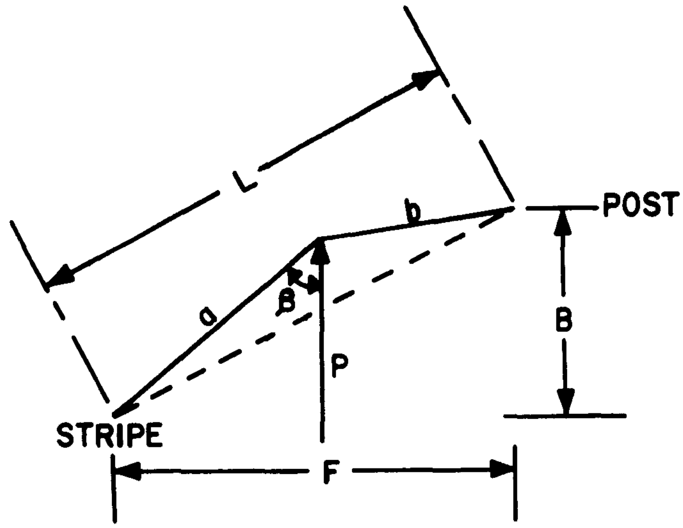


FIGURE 5.3-9

WIRE DURING PULL TEST
WITH CONCENTRATED LOAD

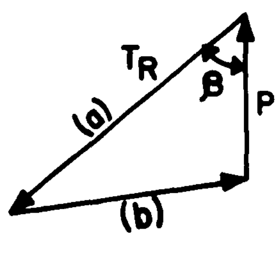


FIGURE 5.3-10

PARALLELOGRAM OF FORCES DURING
PULL TEST WITH CONCENTRATED LOAD

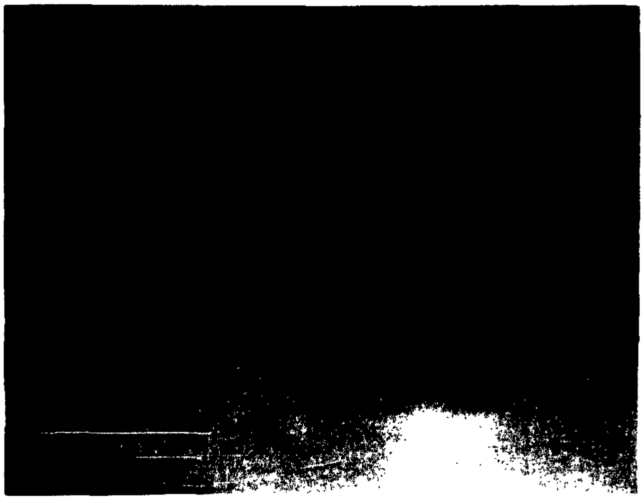


FIGURE 5.3-11

.0005-INCH-DIAMETER WIRE AFTER CENTRIFUGING AT 200,000 G'S

FIGURE 5.3-12

2N559 TRANSISTOR CENTRIFUGED AT 100,000 G'S -.0005-INCH-DIAMETER WIRE BONDED TO SIDE OF POST AS IN MANUAL WIRE BONDING.

FIGURE 5.3-13

2N559 TRANSISTOR BEFORE CENTRIFUGING AT 100,000 G'S - .0005 - INCH-DIAMETER WIRE BONDED TO TOP OF POST AS IN MECHANIZED OPERATION.

FIGURE 5.3-14

2N559 TRANSISTOR OF FIGURE 5.3-13 AFTER CENTRIFUGING AT 100,000 G'S.

VALUES OF T_R AND P FOR DIFFERENT WIRE DIAMETERS AND DEVICE GEOMETRY

B (in)	F (in)	d (in)	T_R (mg)	θ (deg)	P (mg)	P_S (mg)
.015	.035	.0005	70.4	44.5	37	100
.032	.035	.0005	75.9	72	77	190
.015	.070	.0005	222	24	52	130
.035	.070	.0005	134	50	80	200
.032	.053	.0005	100	33	73	180
.015	.070	.001	880	24	203	500
.035	.070	.001	536	50	312	780

Key to Symbols:

B - Post height above stripe (inch)

F - Horizontal distance between stripe and post (inch)

d - Diameter of gold wire (inch)

T_R - Reactive force at stripe bond at 20,000 g's acceleration (milligrams)

θ - Angle of action of T_R (degrees)

P - Vertical concentrated force between post and stripe to create reaction equal to T_R (milligrams)

P_S - Minimum recommended vertical Force (pull test - milligrams): safety factor 2.5

Figure 5.3-15

SECTION 5.4

IMPACT STUDY OF STITCH WIRE BONDINGS

M. K. Avedissian

I General

II Description

III Conclusions

IV Illustrations

IMPACT STUDY OF STITCH WIRE BONDING

I General

In the Stitch Wire Bonding operation, the bonding tip performs two functions: It guides the wire to the point to be bonded and serves as the actual bonding tool. In order to fulfill this function, the bonding tip has a hole through which the small diameter gold wire is guided. At the lower end of the tip the bonding wire or wedge is attached by a welding operation. The gold wire used for the Stitch Wire Bonding operation is supplied by a spool located above the bonding tip.

Stitch Wire Bonding was developed by the Western Electric Research Center in Princeton, New Jersey, and offers the advantages of simple design and speedy wire bonding. Because of these advantages this principle was used for the mechanized wire bonding machines developed as part of this Contract.

The operator uses a pantograph for the X-Y alignment and a lever for the Z-alignment. The speed of approach of the bonding tip toward the stripes on the semiconductor wafers is controlled by the operator while lowering the Z-lever. The first application of this method was for silicon devices. In order to investigate the practicality of Stitch Wire Bonding for germanium, which is known to be more sensitive to mechanical stresses and crystal dislocations than silicon, it was desirable to study the dynamic forces developing during this bonding operation.

II Description

This Special Study describes the method used to measure accelerations and wire penetrations while bringing the bonding tip into contact with the stripes of the semiconductor wafer during Stitch Wire Bonding. Impact forces are calculated and it is shown that below a certain speed of approach the effect of the approach speed becomes negligible.

The approach speed of the tip is strongly limited because the operator must aim for the stripes. It is believed that a speed of one inch per second on the lever knob, which corresponds to .042 inch per second (in/sec) at the bonding tip can be considered as the practical limit when bonding .0005-inch-diameter wire to stripes, .001 inch by .006 inch.

In order to operate at higher approach speeds than usual, the tests were made with another device, which has .002-inch by .004-inch stripes; the .0005-inch-diameter gold wire was retained since a smaller diameter wire will have less tendency to absorb the impact.

Figure 5.4-1 illustrates schematically the arrangement and settings used for this test. An MB Vibrator, MB-Electronics, New Haven, Connecticut, in conjunction with an IRD Vibration Analyzer Type 601, International Research and Development Corporation, Worthington, Ohio, was used to calibrate the entire system. Various acceleration levels were set and checked with the vibration analyzer. The amplified output of the Endevco Transducer, Endevco Corporation, Pasadena, California, produced vertical deflections on the oscilloscope screen (see Figure 5.4-2, A to H). These deflections represent accelerations, eliminating all calibration errors of the components used. The calibration was done with 40 cycles per second. Since shocks or impacts are mixtures of frequencies, a small percentage of error is introduced due to the non-linearity of the transducer with regard to frequency. The manufacturer of the transducer indicates this error to be within ±1 percent.

The following table, No. 1, lists the accelerations corresponding to the displacements recorded in A through H of Figure 5.4-2.

TABLE 1
f = 40 cycles per second

Figure 5.4-2	Peak to Peak Displacement of Vibrator - d(in)	Photograph Div. P/P	Acceleration $d/2\ \omega^2$(in/sec^2)
A	.001	1.2	31.5
B	.002	2.1	63
C	.003	2.6	94.5
D	.004	3.3	126
E	.006	4.6	189
F	.008	6.2	252
G	.010	8.0	315
H	.012	9.5	378

Figure 5.4-3 shows these accelerations versus divisions from peak to peak.

After having the system calibrated, the transducer was cemented to the bonding arm as shown in Figure 5.4-1. Two speeds of approach were selected - 7 in/sec and 3-1/2 in/sec at the lever knob (the respective bonding tip speeds being .294 in/sec and .147 in/sec). Below 3-1/2 in/sec the output signal obtained from the amplifiers was not strong enough to trigger the memo-scope. The tests were made with and without gold wire in the bonding tip. As expected, the absorbing effect of the gold wire was clearly evident. Two photographs of each condition were made for greater confidence in the repeatability of the test. Figure 5.4-4, A to D, shows the results of the tests.

From Figure 5.4-3 it can be seen that Figure 5.4-4B corresponds to 60 in/sec^2 and Figure 5.4-4D corresponds to 18 in/sec^2. These are linear accelerations since the up travel of the bonding tip after contacting the wafer is in the order of .002 to .005 inch. For the purpose of calculation of the dynamic forces, the dynamic moment of inertia of the system must be found. This is done by considering the bonding arm to be a compound pendulum oscillating about its pivot point. The frequency of oscillations was 49 oscillations per minute. Total weight of the bonding arm was 550 grams. Static tip pressure was 15 grams. In Figure 5.4-1, Xo is the distance of center of gravity of the bonding arm from the pivot point.

$$X_o = \frac{6 \times 13}{550} = .142 \text{ in}$$

$$t = 2\pi\sqrt{\frac{L}{g}}$$

length of equivalent simple pendulum:

$$L = \frac{I}{M \times X_o}$$

$$t = 2\pi\sqrt{\frac{I}{M \times g \times X_o}}$$

$$I = \frac{M \times X_o \times g \times t^2}{4\pi^2}$$

M = total mass of bonding arm

t = time for one full oscillation

Xo = distance of pivot to center of gravity

t = 60/49 = 1.23 sec

I = 2.95 in gm $\sec^2$

The dynamic or impact forces can now be calculated with the above information:

For the 7-in/sec lever-knob speed, the linear acceleration is 60 in/sec^2.

The angular acceleration (see Figure 5.4-1):

$$\alpha = \frac{a}{r} = \frac{60}{4} = 15 \ \frac{1}{sec^2}$$

$$\text{Torque } T = I \times \alpha = 2.95 \times 15 = 44.2 \text{ in-gm}$$

$$\text{Dynamic Force } F_D = \frac{T}{R} = \frac{44.2}{6} = 7.3 \text{ gm}$$

For the 3.5-in/sec lever-knob speed, the linear acceleration is 18 in/sec^2

$$\alpha = \frac{18}{4} = 4.5 \ \frac{1}{sec^2}$$

$$F_D = \frac{I \times \alpha}{R} = \frac{2.95 \times 4.5}{6} = 2.2 \text{ gm}$$

If the penetration of gold wire by the bonding tip at different speeds is known and the angular acceleration of the bonding arm considered to be linear with time, the dynamic force can be computed without utilizing the diagram Figure 5.4-2.

Bonds were made at different speeds and the penetration was measured with the vernier of a suitable microscope. (See Figure 5.4-5, A to F.) These bonds were made without dwell time, since relaxation during the dwell time also has an influence on penetration. The following table, No. 2, shows the penetration of gold wire at different approach speed of the bonding lever.

TABLE 2

Figure 5.4-5	Speed at lever-knob V (in/sec)	Penetration S(in)
A	7	.0005
B	3-1/2	.0004
C	2	.00025
D	1-1/2	.00025
E	1	.00025
F	1/4	.00025

It is evident, that below a certain approach speed the variation of depth of penetration becomes negligible, if any is present at all.

Following is the calculation of the dynamic force F_D with the penetration from Table 2:

$$F_D = \frac{I \times \alpha}{R}$$

$$\alpha = \frac{\omega}{t} \qquad \omega = \text{angular velocity}$$

$$\omega = \frac{V}{R}$$

$$\alpha = \frac{V}{Rt}$$

$$S = \frac{Vt}{2}$$

$$t = \frac{2s}{V}$$

Therefore $\alpha = \dfrac{V^2}{2RS}$

V = velocity of bonding tip before contacting area to be bonded

R = distance of bonding tip from pivot point

S = penetration of bonding tip into gold wire

Ratio of bonding tip velocity to lever knob velocity is 1:24.

For 7-in/sec lever knob velocity:

$$V = \frac{7}{24} = .292 \text{ in/sec}$$

Therefore $\alpha = 14.4 \text{ 1/sec}^2$

$$F_D = \frac{14.4 \times 2.95}{6} = 7.1 \text{ grams}$$

This result is very close to the result obtained previously where $F_D = 7.3$ grams.

For 3.5-in/sec lever-knob velocity

$V = 3.5/24 = .146$ in/sec

$\alpha = 4.5 \text{ 1/sec}^2$

$F_D = 2.2$ grams

This result is identical with the result obtained previously.

As mentioned before, it was not possible to measure the impact at speeds below 3.5 in/sec at the lever-knob. The above calculations were made with the assumptions that the acceleration of the bonding arm is linear with time; these results compared with the results on previous pages show that such an assumption is permissible.

Since confidence in the above calculation was established for 7 and 3.5 in/sec approach speeds at the operating knob, the impact at one in/sec operating knob speed can now be computed. For 1-in/sec lever-knob speed:

$V = 1/24 = .0417$ in/sec bonding tip velocity

$\alpha = .585 \quad 1/\text{sec}^2$

$F_D = .287$ grams, which is 2.2% of the static pressure of 13 grams.

From Table 2 it is evident that the penetration of the .0005-inch-diameter gold wire is half the wire diameter at lever approach speeds below 2 inches per second.

Assuming the same condition with .001-inch-diameter gold wire, the impact force can be computed:

Total weight of bonding arm	=	550 grams
Oscillation about pivot	=	67.5 1/min
Static pressure	=	45 grams

$$Xo = \frac{6 \times 45}{550} = 0.492 \text{ in}$$

$$t = \frac{60}{67.5} = 0.89 \text{ sec.}$$

$$I = 5.43 \text{ in gm sec}^2$$

$$V = 1/24 = 0.0417 \text{ in/sec}^2$$

$$\alpha = .292 \; 1/\text{sec}^2$$

$F_D = 0.265$ gm., which is 0.59 percent of the static pressure of 45 gm.

Wire bonding on devices using .001-inch-diameter wire can be performed at higher speeds compared to operation with .0005-inch-diameter wire because of the larger size of the targets which are to be wire bonded. It is desirable to know the maximum permissible down speed of the bonding lever. Let us assume that the maximum permissible pressure increase due to impact is 10 percent of the static pressure. The deformation of the gold wire can be expected to be approximately 80 percent. With this information the velocities can be computed:

Static pressure = 45 gm

$$F_D = 4.5 \text{ gm.}$$

$$F_D = \frac{\alpha \times I}{R}; \quad \alpha = \frac{4.5 \times 6}{5.43} = 4.96 \frac{1}{\sec^2}$$

Bonding tip velocity

$$V = \sqrt{2 \times \alpha \times R \times S} = \sqrt{2 \times 4.96 \times 6 \times .0008}$$

$$V = 0.218 \frac{\text{in}}{\text{sec.}}$$

Bonding lever velocity

$$V_L = V \times 24 = 5.22 \frac{\text{in}}{\text{sec.}}$$

III Conclusions

This study indicates that the dynamic forces developed during the Stitch Wire Bonding operation are well within permissible limits. The gold wire used for the tests had approximately 3 to 5 percent elongation. Different elongation could cause some variation of the forces developed.

The bonding arm used for the tests was made out of steel. It is obvious that making the bonding arm out of aluminum will reduce F_D.

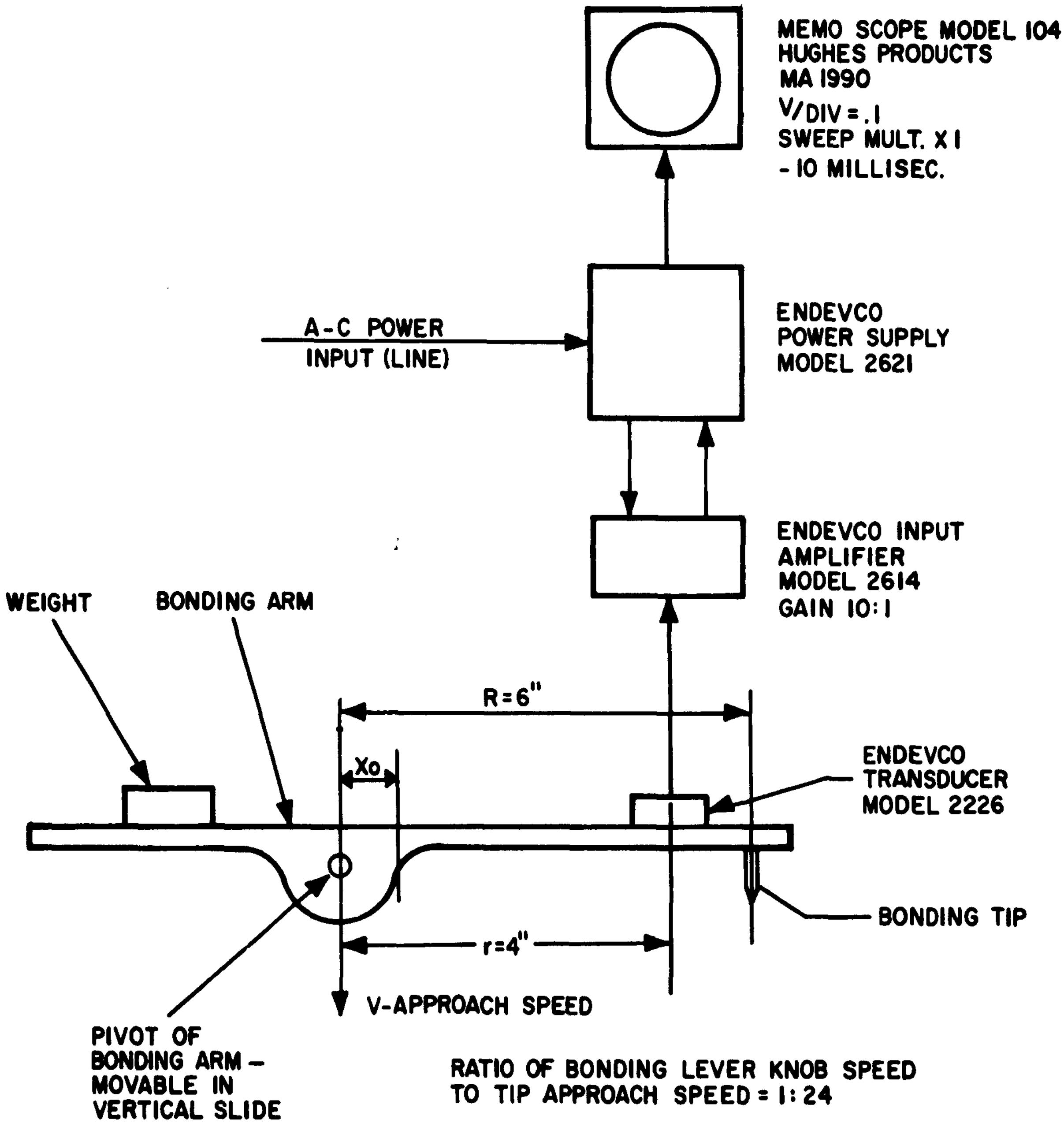


FIGURE 5.4-1

TEST CONDITIONS AND EQUIPMENT FOR IMPACT STUDY

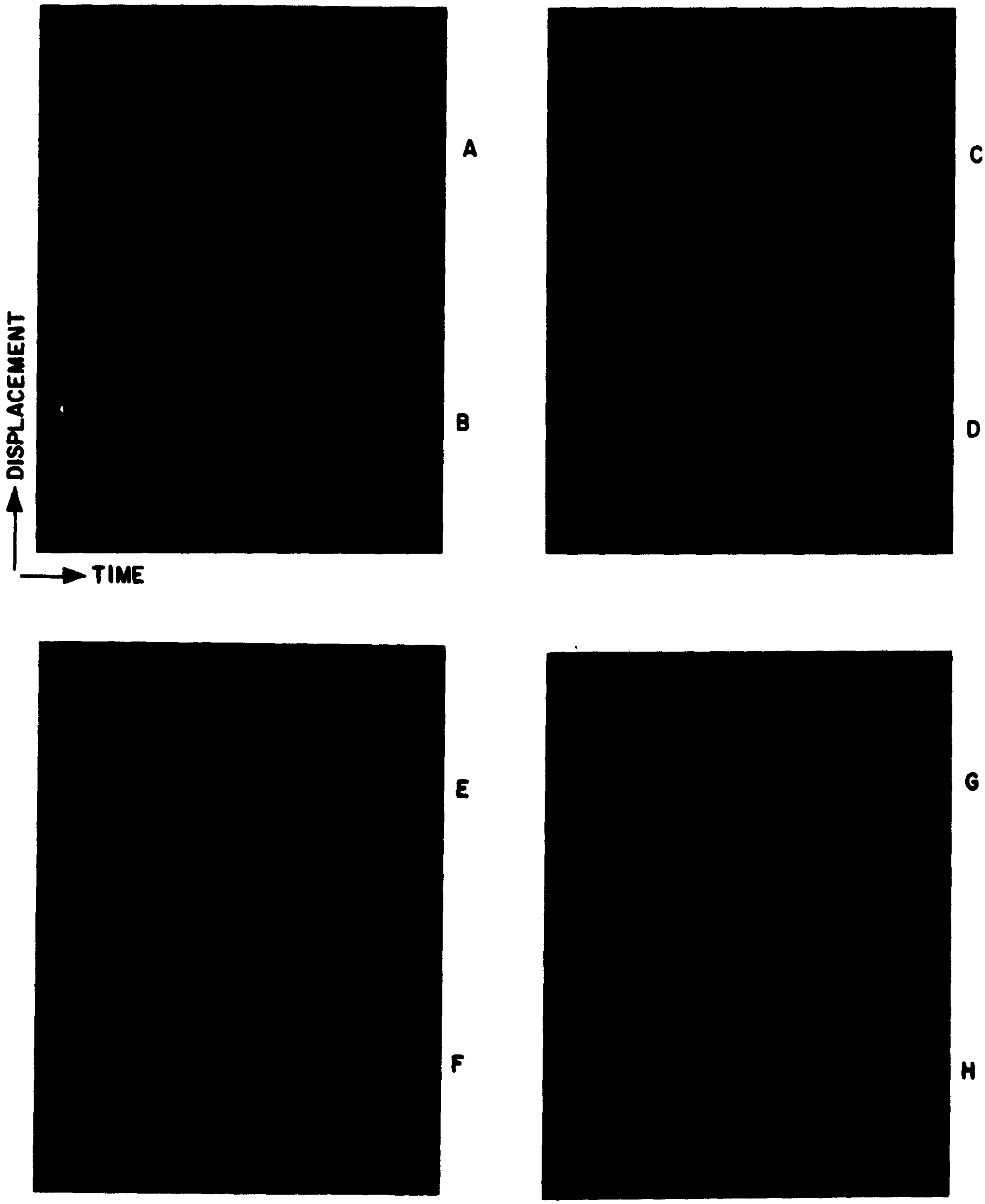


FIGURE 5.4-2

ACCELERATIONS REPRESENTED AS DISPLACEMENT OF VIBRATOR
(SEE TABLE I FOR CALIBRATION)

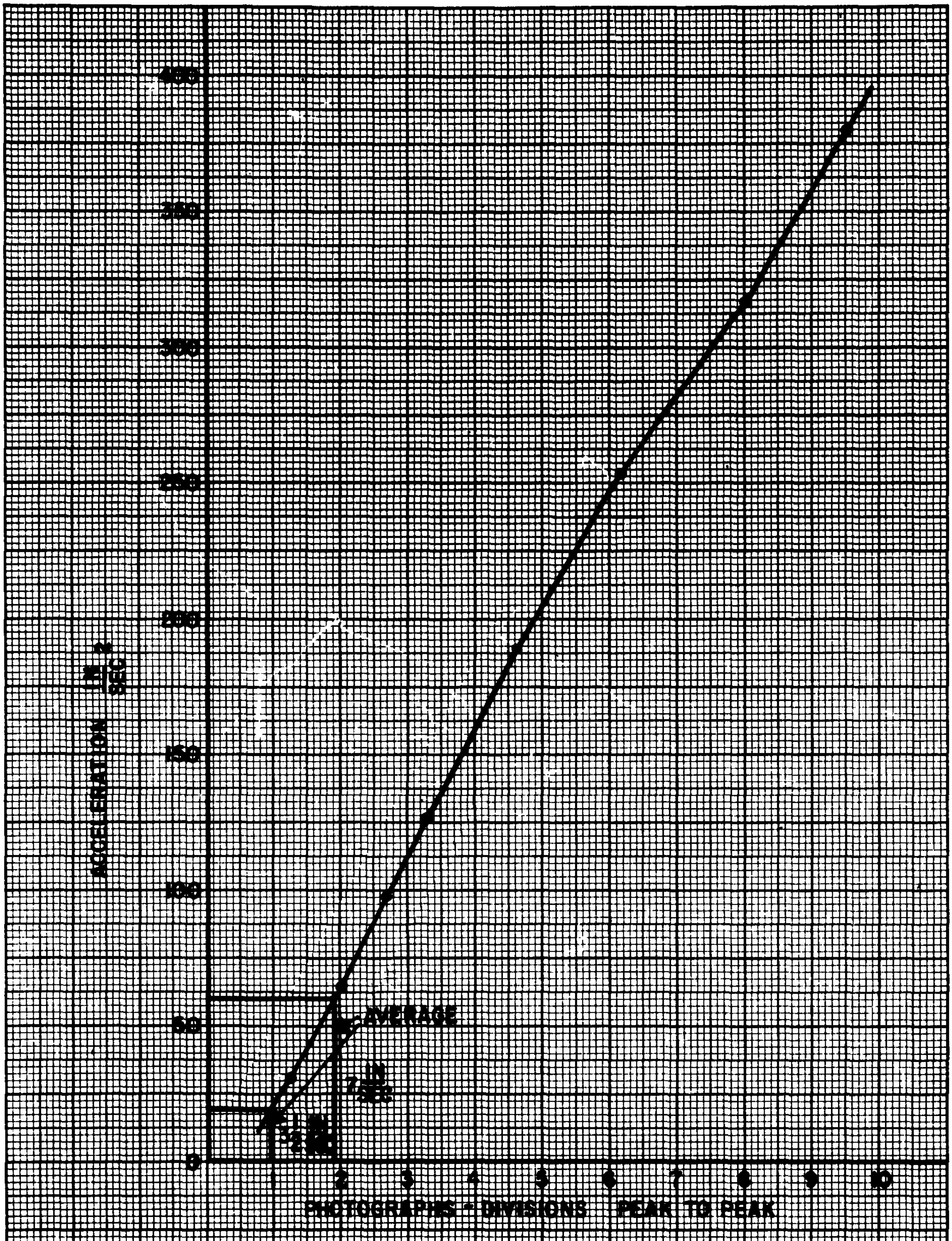
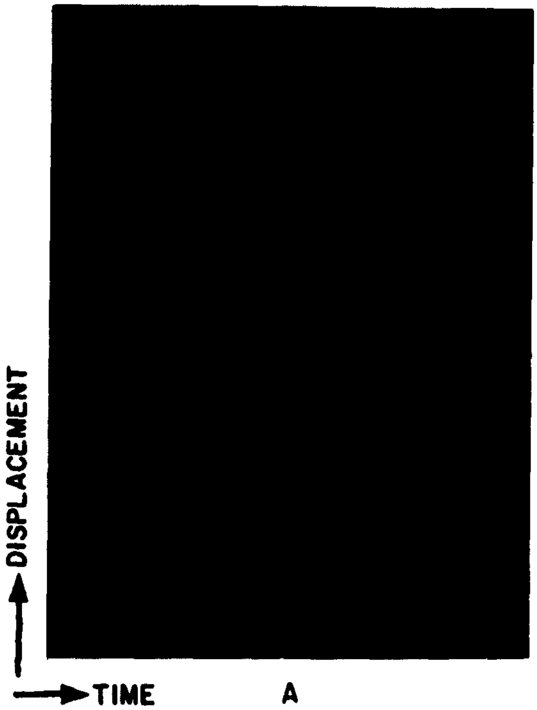
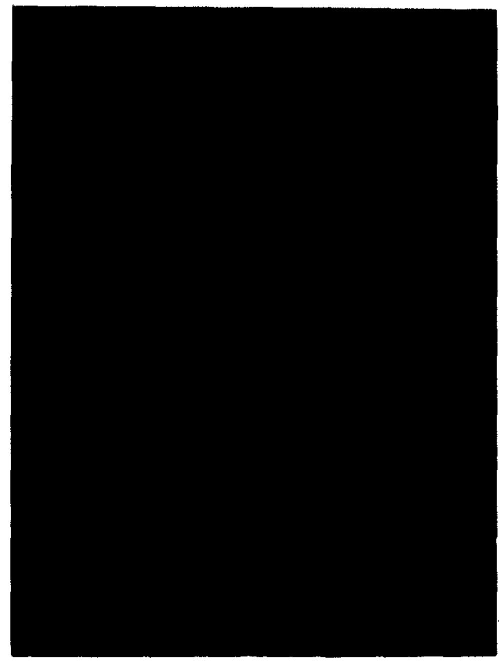


FIGURE 54-3
ACCELERATION VERSUS PEAK TO PEAK DISPLACEMENTS



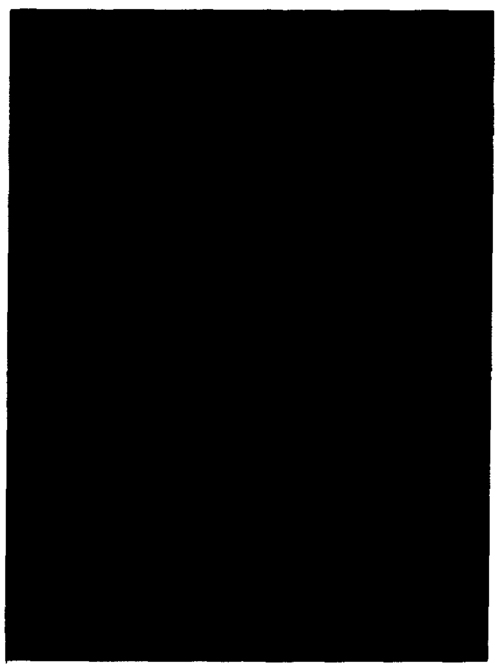
A

$7 \frac{IN}{SEC}$ WITHOUT GOLD WIRE



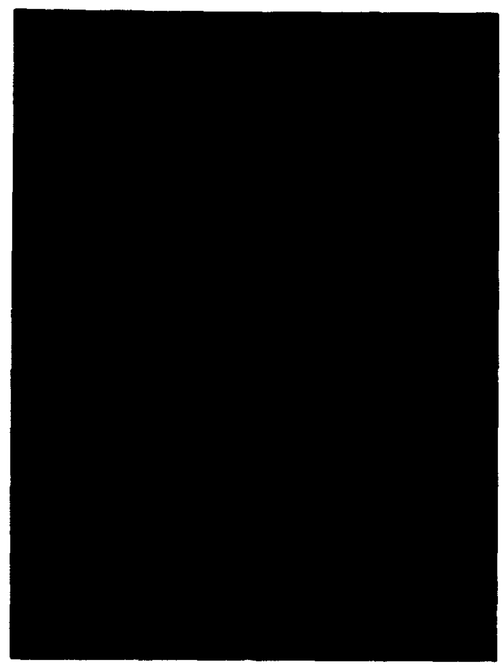
B

$7 \frac{IN}{SEC}$ WITH .0005 IN. DIA. GOLD WIRE



C

$3\frac{1}{2} \frac{IN}{SEC}$ WITHOUT GOLD WIRE

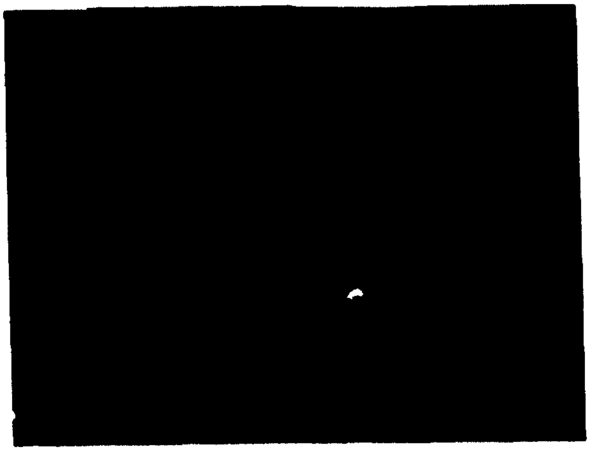


D

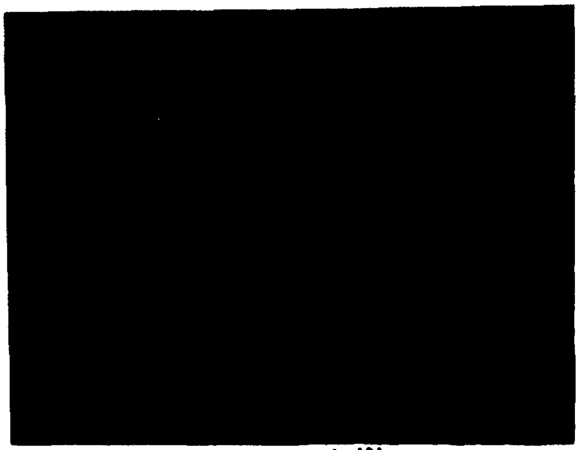
$3\frac{1}{2} \frac{IN}{SEC}$ WITH .0005 IN. DIA. GOLD WIRE

FIGURE 5.4-4

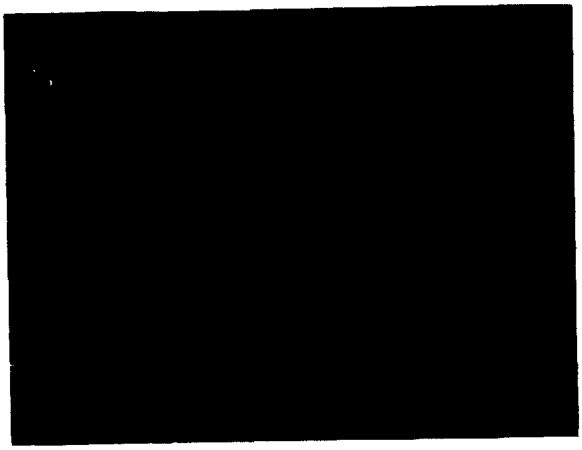
ACCELERATION REPRESENTED AS DISPLACEMENT OF BONDING ARM



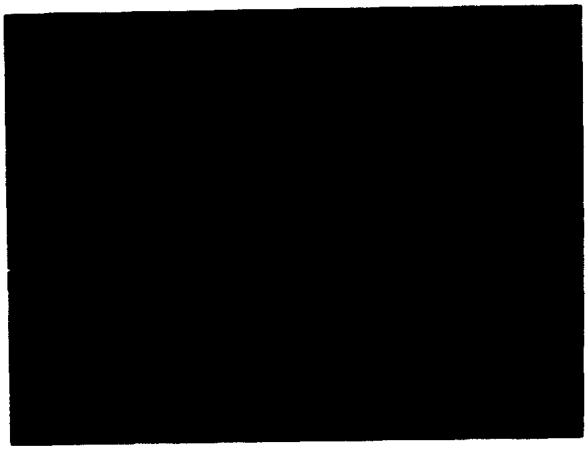
A - 7 $\frac{IN}{SEC}$



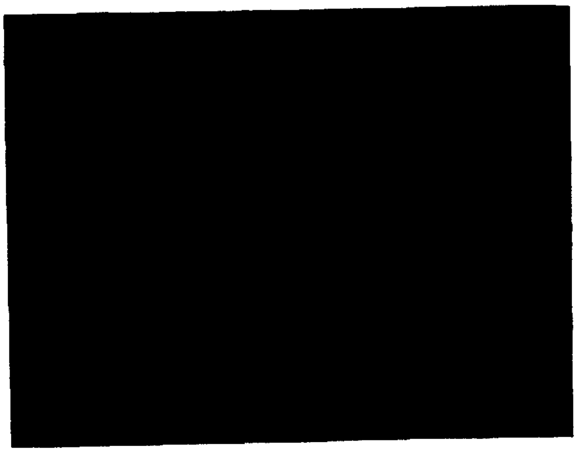
B - $3\frac{1}{2}$ $\frac{IN}{SEC}$



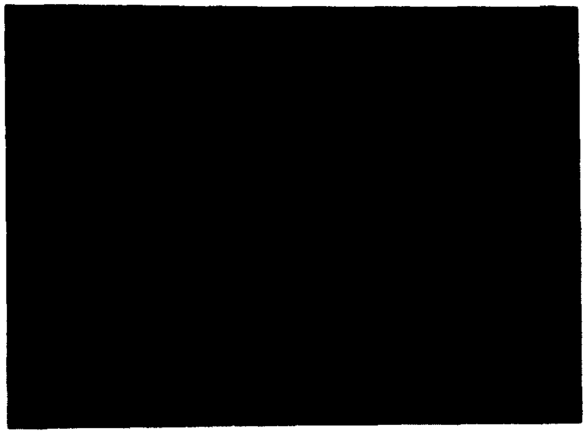
C - 2 $\frac{IN}{SEC}$



D - $1\frac{1}{2}$ $\frac{IN}{SEC}$



E - 1 $\frac{IN}{SEC}$



F - $\frac{1}{4}$ $\frac{IN}{SEC}$

FIGURE 5.4-5

PENETRATION OF .0005" DIAMETER GOLD WIRE AT VARIOUS DOWN SPEEDS OF BONDING LEVER

SUMMARY

The mechanized production line provided for the 2N559 and 2N1C transistors is more versatile than that originally contracted. This made possible by an extension of the Nike Zeus development program. Transistor machines provided under this Contract and Contract No. DA- 039-SC-81294 are now integrated into one production line. Eleven mac of this Contract and 10 machines of Contract No. DA-36-039-SC-81294 c process components for either TO-5 or TO-18 devices. On certain mach an interchange of TO-5 and TO-18 tooling is necessary. Thus, the in- tegrated production line has the capability to process 2N560, 2N1051 2N1195 transistors as well as 2N559 and 2N1094 transistors. It becan practical to integrate the transistor machines of both Contracts in t manner after the transistor requirements for Nike Zeus were reduced.

The Phase 1 production goals were attained, and pilot line cap bility was demonstrated during the 2N559 pilot run. Four distributic of 2N559 electrical parameters were slightly abnormal. In each insta there was an assignable cause. Data collected during mechanized proc tion runs for 2N560, 2N1051, 2N1094 and 2N1195 transistors also indic the quality of these devices was maintained. The 2N559 pilot run anc the four mechanized runs have highlighted areas in which the mechani: operations, unmechanized operations and associated tooling can be im- proved.

The production techniques established have increased the outpu of most mechanized operations significantly. Increases were not rea] by mechanizing certain batch-type operations. In these instances, qu ity of the output was improved so that components could be efficient]

transferred during succeeding operations. The following innovations increased the efficiency of the integrated production line and contributed to the success of the 2N559-2N1094 Mechanization Program:

1. Piece Part Cleaning Without Using Overhead Transfer Mechanisms

   All transfer mechanisms on the Piece Part Cleaning Machine are located at the side and below the cleaning tanks. Thus, the cleaning agents can not be contaminated by dirt, oil and grease from overhead mechanisms. Commercial machines evaluated before developing this machine utilize overhead transfer mechanisms.

2. Electropolishing of Leads

   A microscopic layer of the leads is removed in the mechanized lead cleaning operation by electropolishing or reverse electroplating. This technique has satisfactorily replaced a batch-type furnace cleaning operation which could not supply the straight leads needed throughout transistor assembly and testing.

3. A Combined Oxidizing and Glassing Furnace

   This innovation assures that the oxide coating of the header leads and platforms is not disturbed. It also eliminated a header assembling problem: Handling oxidized leads without disturbing the oxide coating. Oxidizing is now done in the Header Glassing Furnace before the headers enter the glassing zone.

4. Stitch Wire Bonding

   Mechanizing the Stitch Wire Bonding technique has multiplied the output of the Wire Bonding operation approximately four times. Effort of the operator is markedly reduced by supplying small diameter wire to the bonding tip through a small hole and by eliminating the many adjustments required in the manual operation.

5. Attaching a Moisture Getter in a Porous Nickel Sponge

   A mechanically simple 3-step operation was developed to attach a moisture getter inside the transistor cans. Finely ground nickel powder is placed in the cans during the first step. The powder is sintered to form a nickel sponge mass firmly attached to the cans during the second step. Finally, the moisture getter is placed into the cans and fused in the sponge.

6. Gas Flushing Prior to Closure Welding

   The dry-box within a dry-box feature of the Closure Welding Machine provides an ambient within the transistor that is as free of moisture as the gas supply itself. Each welding fixture of the Closure Welding Machine is flushed with dry gas just before a can and header are joined together.

7. Card Mounting of Transistors

   Attaching the 2N559 transistor to cardboard with heat sealable tape has proven to be an efficient and reliable means of handling transistors during testing and, at the same time, maintaining straight leads. By utilizing the same card for packaging, a large quantity of transistors can be packaged quickly and compactly.

The pilot run and the mechanized runs afforded the first opportunity to evaluate the mechanized line. Most machines were tested individually during the shop trials, and major operating problems were overcome. Certain alterations were delayed in order to use the machines during the pilot run. Operating experience to date indicates that the output can be increased by improvements in the following areas:

1. Simplifying setup and maintenance
2. Smoothing out mechanical actions in order to operate certain machines at higher speeds
3. Additionally minimizing the corrosive action of chemical agents on certain machines
4. Development of a method for quickly checking the quality of the gold plate

Engineering efforts will be directed toward refining and updating the mechanized production line during 1963. Process operations as well as the mechanized operations will be improved. Production runs will be repeated during the last months of 1963 to evaluate the modification made during the year.

KEY PERSONNEL

Western Electric Engineering Personnel listed below had prime responsibility for administering the mechanization program and developing machinery during Phase 1 of the Contract:

H. F. Anspach

M. K. Avedissian

J. L. Chapman

C. P. Comins

C. R. Fegley

L. H. Fick

R. R. Field

R. S. Greenberg

R. C. Hermann

H. J Huber

L. Huis, Jr.

R. W. Ingham

H J. Kegerise

D. J. Laverinets

R. F. Lipscomb

D. H. Lockart

R. P. Loeper

G. B. Loughery

R. E. Moore

H. K. Naumann

A. L. Nester

L. W. Rockwood

Q. L. Schmick

G. G. Seaman

L. R. Sell

B. W. Shugars

W. E. Snyder

S. A. Sternbergh

Approximately 105,300 engineering hours were spent by Engineering Personnel of the Western Electric Company, Laureldale, Pennsylvania, on the 2N559-2N1094 Mechanization Program during Phase 1, April 30, 1959 to December 31, 1962. At least one-third of these engineering hours were required for engineering services such as design, drafting, factory planning and laboratory analysis.

During this same period, Bell Telephone Laboratories Personnel and Western Electric Engineering Personnel temporarily assigned to the Laboratories spent approximately 3,200 hours on technical problems and design changes associated with this mechanization program.

PUBLICATIONS AND REPORTS

Quarterly Progress Report Number	Period
7	March 10, 1959 to June 10, 1959
8	June 10, 1959 to September 10, 1959
9	September 10, 1959 to December 10, 1959
10	December 10, 1959 to March 10, 1960
11	March 10, 1960 to June 10, 1960
12	June 10, 1960 to September 10, 1960
13	September 10, 1960 to December 10, 1960
14	December 10, 1960 to March 10, 1961
15	March 10, 1961 to June 10, 1961
16	June 10, 1961 to September 10, 1961
17	September 10, 1961 to December 10, 1961
18	December 10, 1961 to March 10, 1962
19	March 10, 1962 to June 10, 1962
20	June 10, 1962 to September 10, 1962